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AMERICAN ELECTRIC RAILWAY PRACTICE

BY

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AND

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PREFACE

In compiling this book the object of the authors has been to place before the reader a considerable amount of practical information relating to the construction, operation and maintenance of electric railways as they exist to-day in this country. This information they have largely gathered from the columns of the *Street Railway Journal,* and from their personal experience in the various departments of the steam and electric railway transportation business. Theory, except occasionally in its simpler form, has been avoided with the hope that the book will prove of interest to the greatest number of the workers in the railway field. An endeavor has been made to bring this book up-to-date as far as possible and to describe the methods of conducting the work of the different departments as practiced by many of the most advanced roads. The apparatus employed is explained and illustrated with care, and all that which has become obsolete has been omitted.

It has not been the intention to advocate certain methods of management, operation or the handling of apparatus, but rather to describe such as have been adopted with success in different localities, with the view that a choice may be presented to the reader in search of information. It is fully understood that local conditions differ widely and methods well adapted to one road may not be the most desirable for another. No railway officer can be expected to agree with everything contained in the book, but it is believed that in some places he may pick out a new idea which if adopted will prove advantageous in his own case.

Many of the methods employed in steam railway operation are frequently referred to. As the development of the electric railway has progressed, a decided tendency towards the adoption of steam railway practice in a modified form to suit the difference in equipment and operation is noticeable. Those who are responsible for this development now realize that the sixty

years' experience of the steam railway men furnishes many examples of what is best to do and what not to do.

While a considerable number of subjects have been covered, the field is so broad that it is impossible to include everything in one book even if touched upon so lightly as is some of the matter included.

The thanks of the authors are due to the many members of the railway fraternity who kindly lent their assistance in supplying data and statistics which have greatly added to the value of the book.

ALBERT B. HERRICK,
EDWARD C. BOYNTON.

NEW YORK, June 1, 1906.

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AMERICAN ELECTRIC RAILWAY PRACTICE

CHAPTER I

PRELIMINARY ESTIMATES

Probable Earnings

Electric Railways are built to supply transportation between centers of a population large enough to justify the building and running of a railroad to supply facilities for local passenger, express, mail or freight business. The data from which the earning capacity of any proposed road can be approximated are largely drawn from those of similar roads operating in different parts of the country. The different states show considerable variation in regard to that transient traffic upon which the electric railway depends for its revenue.

In estimating the traffic carried by city roads, which are confined within municipal limits, a basis for comparison can be very easily secured. The principal factors affecting traffic on these roads are the distribution of population relative to the center or business portion, the density of population, and the character of the business or manufacturing industries, with their locations. Ohio is a representative state so far as city traffic is concerned and statistics from certain of its cities are given below. The earnings from the four largest cities in the state vary from $12.54 per capita to $10.87. The high figures secured in Cleveland and Cincinnati are due largely to the extent of their manufacturing industries, and to the considerable areas over which the cities are built. The earning capacity per mile of track is larger in Cleveland, which is the largest manufacturing city in Ohio.

Considering now the smaller cities in Ohio, Dayton is served by three roads, and the earnings per mile of track are directly

proportional to the population of the manufacturing districts which each serves. The Lorain Street Railway is another which depends largely upon the transportation of mechanics to and from their work. This class of revenue is very desirable, as it is continuous, and is independent of weather and other conditions, which seriously affect shopping and pleasure traffic. It is very doubtful whether a city electric line, when subject to the usual paving ordinances, and with the present cost of construction, can be made profitable if its gross receipts are less than $4,000 per mile.

TABLE I

TABLE SHOWING EARNINGS OF OHIO CITY RAILWAYS

Cities over 100,000 Population.	Population.	Total Track Mileage.	Total Earnings 1904.	Earnings per Capita.	Per Mile of Track.
Cleveland	381,768	236	$4,544,868	$11.90	$19,258
Cincinnati	325,902	217	3,543,626	10.87	16,330
Columbus	127,926	106	1,444,315	11.12	13.625
Toledo	131,822	110	1,653,220	12.54	15.029
Under 100,000 Population.					
Dayton People's Ry. Co.	85,333	31	298,158	3.49	9,617
Dayton-Oakwood St. Ry.	85,333	8	125,494	1.47	15,688
Dayton City Railway Co	85,333	28.75	423,804	4.93	14,744
Dayton total and averages		67.75	847,556	9.93	13,349
Springfield	38,253	28.6	203,107	5.31	7,102
Mansfield	25,475	21.	139,437	5.47	6,639
Lorain Street Railway	26,656	11.6	95,863	3.58	8,264

TABLE II

TABLE SHOWING EARNINGS OF CITY RAILWAYS IN NEW YORK STATE

	Population 1900.	Total Track Mileage.	Total Earnings 1904.	Earnings per Capita.	Per Mile of Track.
Brooklyn	1,166,582	558	$16,593,530	$14.31	$29,737
Buffalo	352,387	356	4,012,489	11.39	11,290
Albany and Troy	154,802	85	1,704,742	11.01	20,055
Rochester	133,896	151	1,499,719	11.20	9.932
Syracuse	88,143	72	839,373	9.52	11,657

As the fixed charges against the operation of any railway property constitute a considerable proportion of the total cost

of operation, it may be very difficult for short roads, under the usual traffic conditions found in small cities and towns, to make a fair showing. This results in the endeavor to increase business by suburban and interurban extensions of the road.

In the case of interurban railways it is difficult to estimate the probable traffic, and it is therefore necessary to analyze the various conditions and collect all the obtainable data. Unfortunately the census reports on population, outside of cities and towns, are given by townships, and do not indicate the inhabitants directly affected by a proposed interurban road.

TABLE III

EARNINGS OF OHIO INTERURBAN RAILWAYS

	Population.		Miles of Track. Interurban.	City & Interurban.	Total Earnings.	Earnings per Capita.		Per Mile of Track.
	Exclusive of Terminal.	Inclusive of Terminal.				Exclusive of Terminal.	Inclusive of Terminal.	
Lake Shore Electric.....	101,806	615,892	145	160	$610,075	$5.99	$ .99	$3,812
Cleveland Southwestern	78,809	460,577	134	..	447,082	5.67	.97	3,336
Western Ohio..	71,819	116,728	83.5	..	204,806	2.85	1.75	2,453
Columbus, London & Springfield.........	50,764	176,330	52	..	157,200	3.09	.88	3,023
Columbus, Buckeye Lake & Newark...	25,894	151,454	39	..	191,504	7.39	1.26	4,910
Dayton & Western..........	34,081	119,414	30	..	106,293	3.12	.89	3,543
Maumee Valley Ry. & Lgt Co.	8,823	140,645	20.2	..	71,381	8.09	.43	3,533
Tiffin, Fostoria & Eastern....	23,619	43,722	17	..	49,087	2 45	1.12	2,886

Data should be obtained by actual count of the people living in the area 1 or 1½ miles each side of the proposed route. This, with the population of the terminal towns or cities, and of the incorporated villages within this zone, will give approximately the total population affected. Another way to arrive at a rough approximation of the rural population is to assume that the number given by the United States Census for any given township is uniformly distributed over the township, and that

the population in the area included in the strip 2 or 3 miles wide, the center of which is the railway route, bears the same ratio to the total area of the township, as the population affected is to the total population of the township. It is a debatable question as to what effect the population of large terminal cities has on the earning capacity of the road entering these cities. The above table gives data, on population and traffic, of Ohio, both inclusive and exclusive of terminal population, from which an idea can be formed. On account of the lower cost of construction per mile, gross receipts of $3,000 per mile of track is about the minimum when fair earnings can be expected.

Competition with Steam Roads

The following table shows the falling off in local traffic of the Lake Shore and the "Nickel Plate" roads and the enormous gain of the trolley roads between the same points.

Table IV

LAKE SHORE AND MICHIGAN SOUTHERN RAILROAD: PASSENGERS CARRIED BETWEEN CLEVELAND AND OBERLIN AND INTERMEDIATE POINTS

	Westbound.	Eastbound.	Total.	Average per Month.
1895	104,426	98,588	203,014	16.918
1902	46,328	45,433	91,761	7,647

Table V

LAKE SHORE AND MICHIGAN SOUTHERN RAILROAD: PASSENGERS CARRIED BETWEEN CLEVELAND AND PAINESVILLE AND INTERMEDIATE POINTS

	Westbound.	Eastbound.	Total.	Average per Month.
1895	97,460	101,832	199,292	16,608
1902	13,106	15,602	28,708	2,392

Table VI

NEW YORK, CHICAGO AND ST. LOUIS RAILROAD: PASSENGERS CARRIED BETWEEN CLEVELAND AND LORAIN

	Total Passengers.	Receipts.	Average Receipts.
1895	42,526	$25,523	60c.
1902	9,795	4,379	44c.

In 1902 the trolley road between Cleveland and Lorain carried over 3,000,000 passengers.

Between Ann Arbor and Detroit the local traffic of the Michigan Central was about 200 passengers per day before the opening of the electric railway between those points. During its first summer the electric road (The Detroit, Ypsilanti, Ann Arbor and Jackson) averaged approximately 4,000 passengers per day, between the same cities.

Between New Britain and Hartford, Conn., a distance of 9 miles, prior to 1897 the steam road service consisted of eight trains each way per day, and the fare charged was 22 cents one way. The average number of passengers per day was nearly 400.

In the above year the New York, New Haven & Hartford Railroad, which controlled the steam road mentioned, equipped one of the tracks with the third rail and put on a heavy high speed service running half-hourly for eighteen hours, making thirty-six trains each way per day. The time was a little faster than the steam service, being eighteen minutes for the nine miles, with two stops. The fare was cut to 10 cents one way. The traffic after the first few weeks settled at about 2,000 passengers per day for the first year, and has steadily increased ever since. This was simply due to the improved service and reduced fare as there was no competition at the time the road was opened.

Interurban Railway Location

The lighter types of interurban roads are usually built along the side of the highway and coincide with it in grade. The location is such that vehicles are seldom compelled to encroach upon the track and the use of T-rails above ground is possible. High speed is rarely attained on these roads due to the necessary grades and curvatures encountered. The heavy interurban roads are nearly always built on a private right of way, except when they pass through towns, and this class of construction will be chiefly discussed.

On the "man behind the transit" or the locating engineer, much depends. Railroad location is an art acquired only by years of experience, and the engineer should know that interurban railway location is always a compromise between the

steam railroad and the street railway. However, the heavy, high speed interurban roads are now located with almost the same care as to grades and alignment as are the steam roads, and their track construction is fully as good as the average steam road. An old railroad adage says the prime requisite in good road construction is drainage, and the next is better drainage. An engineer who locates a sag or hollow between two opposite grades in a cut, either cannot avoid it or does not know what drainage means. Too often we are apt to see a new interurban road opened for traffic with the rails and ties practically laid on the sub-grade, and no ballast worthy of the name. Electric interurban roads are not the only ones built in this way. Not a few steam roads, especially west of the Mississippi River, are built with the rails laid on the prairie, and in the spring of the year when the frost comes out of the ground, and the track heaves, railroading is anything but pleasant, as "the train only hits the high spots." But this latter condition in the case of these steam roads is often obligatory, for ballast is hard to find and is expensive, so ballasting is postponed until the road earns it.

Wellington says regarding steam road location that, "The locating engineer has but one end in view to justify his existence as such, to get the most value for a dollar which nature permits; and but one failure to fear, that he will not do so." This remark is equally true of the electric railway.

It is in the location of the route that we have principally to bear in mind the conditions in the road under construction which will affect the earning capacity when it comes to be operated. An electric railway can be broadly considered a factory for transportation. Serious errors have been made in the past because of the casual way in which such roads are usually laid out. A pencil line on a map, usually a geological survey map, is often taken for the basis of the route of a road, without proper consideration of the engineering and commercial side of the question. These latter considerations have an enormous effect upon the operation and earning capacity of the property during its life. In many cases after a road has been in operation for some time, further capital has been required to make changes, which careful location and engineering in the first instance would have rendered unnecessary.

Curves and steep grades which could have been obviated by a small increase in first cost, have been allowed through the parsimony or ignorance of the locating engineer.

A number of roads could be mentioned which have gone into the hands of a receiver from causes that arose through carelessness or ignorance in the original location of the road, by which, unnecessary hazards in operation, increased depreciation and unnecessary power consumption were caused. Immediate local conditions in the preliminary engineering had been given too great a bearing, and the future of the property, the vital point in the construction of the road, was forgotten.

The following faults are among the principal ones a locating engineer should avoid where possible:

Locating curves at the foot of grades.

Locating curves where approaching cars are not visible to each other.

Locating curves and turnouts at the approach to bridges.

The use of unlocked facing point switches.

Crossing a highway oftener than is absolutely necessary.

It is good policy to pay an abutting property owner his price, and save it in the future damage account.

Changing grades too violently. (Use easy vertical curves.)

Attempting to plan a high speed railway on a highway.

There is no excuse, however plausible, which can be accepted as an apology for poor engineering. If the property is not sufficiently capitalized to produce a good paying railroad, it is better to shorten the road, or economize in those forms of construction which can be improved while the road is in operation, rather than make vital errors in its location. The electric railway to-day is passing through the same evolution with regard to construction and maintenance as was experienced by the steam road.

Preliminary Surveys

The preliminary reconnoissance and choice of various possible routes, both in regard to future traffic and cost of construction, requires experience, but if one has good judgment and an accurate eye the art is readily acquired. The topographical features of the country that lies between the terminal points have to be considered in connection with the character of soil,

the slope of the land, direction of water courses and their area of drainage, as well as the deflections of route decided on to increase traffic. These physical conditions should be considered in all of their aspects.

The tools needed are: An accurate sighting level, which should be looked through with one eye while the other takes in the natural conditions of the points on the same level with the point of observation; a pocket compass, and all the maps that give information in regard to the country through which the road is to be located; assistants who are familiar with the country are a great help in getting a mental picture of the area through which the line will run.

There is only one route which is the best in each case and careful reconnoitering of the country, without having the mind biased by any preconceived preferred route, will approximately locate the best route over which the final surveys will pass. The mind should not be misled into forming hasty judgments. A highway looks much more attractive than ground covered with brush or timber; but the surface appearance should not influence the engineer: the best line to sub-grade is the problem that should be before his mind always. The results of a reconnoissance should appear in notes, the index for such notes being the station numbers on the maps, and the line laid down on the maps with reference figures corresponding to these locations. Experience should be sufficient to enable the engineer to give figures for the cost of cutting and filling, the span of bridges and their cost, so that the approximate cost can be given of different sections of the road generally in mile lengths, in his preliminary report. Experience will also lead the engineer to allow for his personal equation in computing these costs; but the whole question is a matter of good judgment and an accurate conception of the relative values to be dealt with. It is best to have the approximate costs made out as the party advances, so that the local physical conditions are under review while the costs are being computed. A careful reconnoissance should find among all possible routes, one route for which the permanent survey should be made, or possibly two, for the final location of the road.

In the case of roads following highways the preliminary survey has only to deal with the selection of the proper side of

the highway, whether the road can follow the grades of the highway without profitably cutting and filling; whether tangents cannot be preferably made rather than following a sinuous highway; whether cuts through private right of way cannot be made from one point of the highway to another in order to avoid curves and to reduce both length and the cost of the road. Also along what streets it shall enter the terminals, as well as the general physical condition of the highway, the character of embankments against which the road has to be built, the foundation conditions and the length of spans for bridges.

The Location of City Lines

In locating a street railway there are many matters which should be given careful attention before deciding on the route. The streets selected should be the main thoroughfares, and such streets leading into them as seem to promise the most traffic. The geography of every city is different, but in general, lines connecting the business and manufacturing districts with the residential sections are always wanted. Numerous examples are to be found where the city road has built lines leading toward uninhabited sections near the outskirts of the city, and in a short time the section becomes well populated. The obtaining of a franchise for a right of way through the streets selected is frequently a game of politics, and it is often necessary to make the best compromise possible as regards what streets the railway shall be permitted to use.

The questions which are to be next decided are chiefly engineering problems and pertain to the location and character of the track. On what streets to lay double track; and when single track is used, where to locate turnouts, are questions which require a careful study of the probable traffic, both at the start and far into the future. An estimate of probable future traffic is little more than a guess, with only the experience of other cities as a guide, but it involves the future maximum schedule and the size and number of cars.

The track center distance for double track is very important, as it determines the width of the cars and the clearance between them. Single truck cars require less clearance, both on tangents and curves, than double truck cars. The latter, being mounted on swinging bolsters, have been known to strike when

passing at comparatively high speed on straight track, when the clearance was ample for single trucks. The clearance used in different cities varies, as can be seen in Fig. 81 in the section on "Proper Types of Cars," which gives track centers, widths of cars, and clearances used in several of our largest cities. In general there are two clearances, a narrow one of about 12 inches, so that a person cannot stand safely between passing cars, and a wide one of 18 inches or more which enables a person to so stand between the cars. Any clearance between 12 and 18 inches might prove hazardous and add to the damage or accident account.

To determine track centers, add the clearance, or distance between cars, to the greatest width of the car body. Subtracting the gauge of the track from the track center distance will give the width of the "devil strip" or distance between tracks, measured from the gauge lines. Particular attention should be given to track centers on curves, if it is desired to pass cars at such points, and the problem should be carefully laid out on paper with reference to both single and double truck cars. If overhead bridges are encountered the headroom should be carefully determined with reference to the cars it is proposed to run beneath them.

In turning into narrow streets the short radius curves should be laid out in such a manner that the car body will clear the sidewalk and all obstacles such as trees, poles, etc.

CHAPTER II

FIELD ENGINEERING FOR INTERURBAN ROADS

Permanent Locations

When the road has been located by reconnoissance, and the best route selected, or at doubtful points trial lines mapped out, the survey is undertaken. This survey is based on the preliminary notes, aided by topographical maps showing the general elevations and physical conditions adjacent to the route selected. It should be borne in mind, when questions arise involving construction costs, that the outlay for surveying is a very small proportion of the total cost of construction. No labor or pains should therefore be spared in making these surveys, and when in doubt, mapping out and running trial lines. Otherwise natural features may be overlooked, which, if taken advantage of, would materially reduce the final cost of construction.

The results of these surveys should be accurately embodied in maps, exhibiting clearly in detail the topographical features, and the location of the levels, which may be either taken as the sub-grade or the base of the rail. In level-country work the base of the rail is generally taken, but where cuts and fills are required the sub-grade is used for this purpose. From these surveys the calculations of earth-work are made. Sections should be drawn showing the natural contour of the earth,—the distance between these sections being dependent upon the irregularity of the ground. The cross-section of the depth of cut, or fill, should be detailed, at every point along the cross-section where the surface slope changes rapidly. The mapping should begin immediately with the adjustment of the first tangent; the scale of 1 inch to 100 feet is generally selected where the conditions are normal, but 1 inch to 50 feet is often used where the engineering features are difficult, as when the line is to pass through thickly populated districts, or where complicated adjacent land lines occur.

To aid in the completeness of these maps for the purpose of estimating costs, symbols or colors are used to designate the character of obstructions on the surface of the ground, and also to indicate the character of the soil, and the probable character of the subsoil, where surface indications give a clue. Another set of maps of wider scope should also be drawn up to cover the same sections. These must be marked either with initial letters or designating numbers, so that the same sections on the two different sets of maps can be identified. These latter maps should include such structural features as appear along the right of way, the allowed encroachments of abutments or other structures, the property lines, fence lines, private and public roads and steam road crossings. This land map generally covers a territory from 100 feet to 600 feet each side of the right of way. The land maps should be made on durable white paper, preferably backed with linen. All these maps should be of uniform size, so that they can be bound, paged and indexed for ready reference, as the field work progresses. One of the principal values of such maps is the aid they afford to the real estate agent in securing the right of way, enabling him to compare them with the abstracts of deeds of the property abutting on the right of way. They should correspond to the county, city and tax maps through which the right of way passes.

The structural maps will derive much of the information from the land maps, but will add further details of the structure and physical features along the right of way, the locations of the tracks, the position of all side monuments, stations and benches, bridge abutments and locations, culverts, buildings and fences. North should be plainly marked by the conventional arrow on each map. The ends of tangents, the radii of curves connecting tangents, and of the transitional curves used to enter from the tangent to the curve should be indicated. In some cases the curve is given in degrees of deflection for a 100-foot chord, but the radius of the curve is generally given in electric railway work. The profile line of the completed road sub-grade is also laid out. A very complete map can be made on one sheet, the physical map passing through the center, the profile at the bottom of the sheet, and the cross-sections of cuts and fills, length of spans of bridge, culverts and location

of bridge abutments at the top. The cubical contents of cuts and fills is given for each section between adjacent cross-sections, the width of the sub-grade, ditches and slopes of cuts and fills. Accuracy and clearness in mapping out an electric railway affect greatly the contractor's estimates. Where this work is to be given by contract, every element left in doubt, or omitted, increases the cost of the bid to cover the risk of underestimating.

It is not within the scope of this book to go further into details of the actual making of a survey, except to call attention to its important relation to the economy of operation and to the limits within which the surveyor is controlled by engineering conditions under which schedule speeds can be made with safety. While the electric railway has heavier grades and sharper curve-limits than the steam road, the surveyor should be instructed by an engineer on the marked effect grades and curves have on the operating economy, and what modifying effect the reduction of these will have on cost of operation. A few examples will best illustrate the bearing of these on the general problem.

In the matter of limiting grades, the question is how much an increase in the cost of construction will decrease the cost of operation. If $20 can be spent in construction to save one dollar in operation the expenditure is earning a five per cent. rate of interest at the point where the change is made and the economy effected. It is, however, the summation of all economies which can be obtained by careful preliminary engineering which fixes both the capitalization and earning values of the property. The question is even a broader one than this, especially on certain critical lengths of road.

Assume, for example, a road between 17 and 20 miles long, with one hour between the departure of the cars from the terminals. If heavy grades and sharp curves are employed, two cars cannot maintain this schedule with safety, and three cars will be required, thereby increasing the cost of operation from 18 to 28 per cent.; while the passenger revenue will be no greater. A greater number of stops will shorten this critical length of the line as regards two or three cars performing hourly service between terminal points.

Considering the effect of grades, assume the case of a grade

1,000 feet long, and a three per cent. compared to a five per cent. gradient. The cost of reducing the five per cent. grade to the three per cent. grade would possibly be $3,500. The relative value of the two can be computed as follows:

Assume a car weighing 25 tons geared to 40 miles per hour on the level, and capable of a schedule speed of 20 miles per hour including stops and slow downs. This car should ascend the five per cent. grade for 1,000 feet at an average speed of 17 miles per hour in 40 seconds. It has gained an elevation of 50 feet and increased its potential energy 2,500,000 foot-pounds at the top. To do this work in the time given the motors would be required to develop 108 horse power. Under the best average conditions of conversion and transmission the power station would have to deliver 216 horse power during the time that the car requires to surmount the grade.

Considering a three per cent. grade of the same length, this car would gain an elevation of 30 feet and a potential energy of 1,500,000 foot-pounds. With an average speed of 21 miles per hour the time required to ascend this grade would be 30 seconds and the horse power from output of the motors 91, or 182 horse power produced at the station.

The time saved between the two grades is 10 seconds, and the output saved at the station would be the difference between 216 and 182 horse power, or 34 horse power for 30 seconds and 216 horse power for 10 seconds, by the use of the lesser grade. At a cost of $.01 per horse power hour this would be a saving in energy alone of $.0088 each time the car ascended the grade. The cost of time at $4.60 per car hour would mean an additional saving of $.0127 per car hour.

Now if we assume half-hourly schedules at terminals, a symmetrical grade on each side, and a 20-hour day, the cars would ascend the grades 80 times a day and the saving in power between the three and five per cent. grades would be $.70, while the saving in cost of time would be $.26, or a total saving of 96 cents per day. This amounts to $350.00 per year or 10 per cent. on the investment of $3,500, the cost of reducing the grade.

Three per cent. was taken as the limit because an ordinary equipment will float down a three per cent. grade at the schedule speed, whereas on a five per cent. grade the brakes have to be applied to keep it within speed limits. In this con-

sideration other capital expenditures are involved, depending upon the location of the grade relative to the power station, which will increase the cost of feeders necessary for the five per cent. grade, in order that the time schedule could be maintained. Also if this is the maximum grade on the route it might increase the capital outlay required on account of the extra demand in the power station, and this is especially true if the meeting points are at the top of the grade, and the maximum demand for both equipments occurred at the same time.

For each particular case the rate of interest on the cost of greater reduction, can be equated against the operating expense required in surmounting the proposed grade as compared to that required for the reduced grade.

A sharp curve is as detrimental to high speed as a heavy grade, for when the curvature approaches 10 or 12 degrees it always means a slow down which is as expensive as a stop. All curves should be of long radius, such as steam roads employ, and they can then be taken at speed.

An interesting discussion of the effect of frequent stops on energy consumption, operating expense, and schedule speed, in comparatively high speed running has been written by Mr. A. H. Armstrong, from which we quote as follows:

Assume a certain road to require a schedule speed of 25 miles per hour, operating 35-ton cars; wanted, the relation between frequency of stops, energy consumption, maximum speed and motor capacity demanded. The following table is made out for an accelerating and braking rate of 1¼ miles per hour per second, a value sufficiently high for suburban work.

TABLE VII

SCHEDULE SPEED 25 MILES PER HOUR

Stops per Mile.	KW.	Maximum Speed.	Total HP Motor Capacity.
0	29	25 miles	143
.2	35	29 "	175
.4	44	31 "	186
.6	51	33 "	207
.8	63	37 "	245
1.0	79	43 "	301
1.2	100	51 "	395

This table affords means of very interesting comparisons. The number of stops per mile given is the equivalent number of stops, and includes slow downs required for sharp curves, etc. With .8 of a stop per mile the power consumption is given as 63 kw. per car, while an increase of 50 per cent. in the number of stops to 1.2 per mile increases the power consumption to 100-kw. average. A further increase in the number of stops and the maintenance of the same schedule speed would increase the power consumption of the car at a much greater ratio. This increase in power for the more frequent stops can be capitalized. The difference in power consumption between .8 stops and 1.2 stops, 37 kw., corresponds to 1.48 kw.-hours per mile of track per car per day. Assume, 1-hour headway and 18-hour service, there will be thirty-six cars per day operating

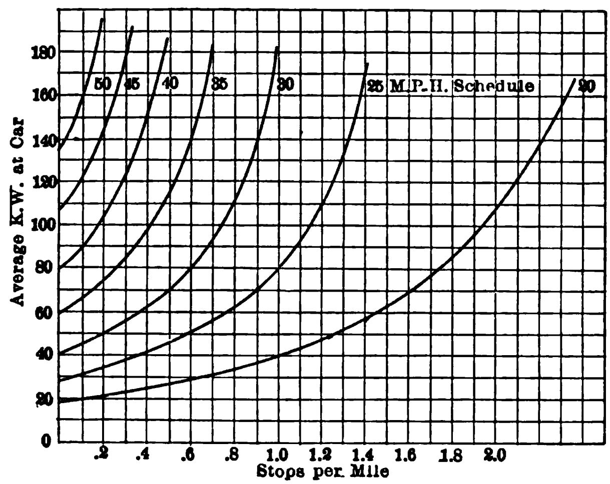


FIG. 1.—Power Consumption at Different Schedule Speeds as Influenced by Stops per Mile.

over this 1-mile section, consuming a total of 53.2 kw.-hours. At 1 cent per kilowatt-hour this energy amounts to 5 per cent. interest on $3,880. In other words, nearly $4,000 per mile of track could be expended to eliminate curves, which would decrease the number of stops per mile 33 per cent.

The results of this investigation are shown graphically in Fig. 1.

To illustrate the influence of more frequent stops a case has

been assumed where a 35-ton car is geared for 45 miles per hour maximum with an equipment of 300-horse power nominal capacity in motors. The following table gives the proper frequency of stops, with varying schedules for the same temperature rise, approximately 60 degrees C. That is, given an equipment operating at 45 miles per hour maximum speed, the table will show the reduced schedule speed required with increasing number of stops, such as would result from increased popularity of our suburban system:

TABLE VIII

45 MILES PER HOUR MAXIMUM SPEED

Schedule.	Watt Hours Per Ton Mile.	Car Power. KW.	No. of Stops Per Mile.
45	67	106	0
40	72	101	.18
35	79	97	.4
30	89	93	.7
25	100	87.5	1.08
20	120	84	1.8

The table shows that a car capable of making, say, 35 miles per hour, with one stop in 2½ miles, would have its schedule speed reduced to 25 miles per hour, should the traffic demand stopping every mile. It is, of course, possible to make somewhat higher schedule speed with one stop per mile than 25 miles per hour, but the increased acceleration required would demand commutation requirements in excess of the capability of the motor.

In the past, electric railway engineering in regard to location and road-bed construction, has not been considered with reference to final economy. The decision seems rather to have been based on how steep a grade will the equipment take. Too much emphasis cannot be laid on the economical factors entering into the construction of the road-bed on which the future success or failure of the property rests. In a number of the properties which have passed through the receiver's hands, the conditions which have involved these roads in financial trouble have arisen from the haphazard and thoughtless methods which were used in their location, and in preliminary engineering.

The Real Estate Agent

Many cares and responsibilities rest on the real estate agent during the promotion and location of an electric railway. The tact which he possesses and his knowledge of the people with whom he has to deal have an important bearing both in the cost of the right of way, and on the attitude of the people towards the railway company locating through their districts. As these people are the future customers of the road, it is important that the relation maintained be one of equity and good feeling. In some communities the residents, recognizing that the electric railroad will be a benêfit to them personally, and should increase the value of their property and products, will often deed rights of way and easements gratuitously, or for a nominal consideration. Again, the right of way is granted under certain stipulations, which at first glance may seem a slight concession on the part of the railway, but which may eventually react against the proper operation of the road. The location of stops,—(the point of maximum economy being on top of grades and at sidings,)—the giving of passes over the road, the hauling of freight and of produce at predetermined charges, are all concessions which should be yielded with the greatest caution, as they involve the future of the road. In all cases fixed rates should be deferred until the natural laws of competition and demand determine them; then a road can reduce rates and increase business, but it often militates permanently against revenue to increase rates.

Property holders often want the road to pass through certain portions of their property, where the land has less value, or where the road will not cut up their fields. They often demand that a road shall be so located as not to destroy shade trees. As a rule the property owner prefers that the right of way should be through his neighbor's possessions rather than through his own. In this relation between the property holder and the railway company the real estate agent is an important factor. He should be in close touch with the engineer, who will indicate to him the best locations, and what local conditions are most favorable; what points to concede, and what points to reject, or where conciliation will work for the best interest of the railway property, both in regard to operation and

engineering. The engineer will also furnish him with the facts by means of which the agent can make his claims in clear and strong terms. The agent should familiarize himself with the legal limitations; with the right of property owners to convey their possessions; and should ascertain who has title to the property in question; and also what are the laws covering deeds and grants in the territory through which he expects to operate.

There are certain communities which are blinded by the obvious advantages gained by transportation facilities, and look on a corporation as a thing to be bled, greed being their dominant motive. The way these localities are frequently handled is to use this motive to obtain the end in view. This is done by running several routes through the country, and when the inhabitants find they will probably lose all by holding the prices of right of way too high, they succumb. This method usually results in considerable shrinking in valuation, and it is best, under these conditions, not to force the most favorable right of way until the last. The amount of land required per mile for different widths of right of way is given in the following table:

A	100-foot	right	of	way	takes	12.1	acres	per	mile.
A	60 "	"	"	"	"	7.26	"	"	"
A	50 "	"	"	"	"	6.05	"	"	"
A	30 "	"	"	"	"	3.62	"	"	"

In the question of settlements,—whether the payments shall be made in cash, bonds, stock or other values,—the financial interests of the road in each case usually decide this question for the agent, unless a fixed policy has been decided upon by the stockholders.

When a franchise has been granted along a highway, abutting property holders will often interfere with the running of the best route; raising objections which are pertinent to them, but these should be overcome by tact and firmness when they involve certain conditions:—such as the crossing of public and private roads. This should be strenuously avoided, for the line of the road should be laid out with the direct intention of making these crossings as few as possible, and it is particularly true where the road is required to cross the highway which it parallels. Shade

trees, line fences, and out-buildings are often obstacles which are sufficient, in the mind of the abutting property owner, to make him insist that the road shall take the other side of the highway. The agent should be instructed in the danger resulting from the frequent crossing of the highway. In the past these trivial objections have too often been given undue weight, because the operating hazard was not understood. The waste of time which the making of every crossing involves is not sufficiently considered: it always means a slow down, and in the crossing of a country dirt road there is usually a poor condition of traction, and derailments are frequent at these points, due to the low obstructed rail head.

Letting Contracts

It is essential that both the engineer and the executive should have a brief outline of what constitutes a valid contract, and what points are generally covered in such contracts, both on the part of the company and the contractor, in the building of an electric railway. It is not the purpose of the authors to give a form, as these vary with each writer of contracts, but an outline of the essential principles which should be included in every contract under which electric railway work is performed. The difference between a contract and a specification is hard to define, as one merges into the other, but care should be exercised that repetitions of the same acts and duties shall not appear both in the contract and the specification, as this will only lead to confusion. But there are elements in a contract which essentially belong to the contract alone.

Among the legal conditions which must be present to make any contract valid, the first is that both parties have the capacity to enter into a contract. Married women, aliens, convicts, infants, insane persons and drunkards, are recognized as incompetents, as parties to contracts under certain conditions, but varying with the laws of different states. The officers of the company contracting may not be competent to execute a contract. The powers conferred upon them by their charter, grant or franchise, their board of directors or stockholders, and the legal rights of the parties concerned have to be examined before drawing the contract.

It is especially difficult for an engineer to draw an impreg-

nable contract. He has to assume at the outset that both parties may be inclined to interpret obscure statements to their own advantage. So no subversion of the evident intent of the duty to perform, can be implied, or doubtful terms used in the statement of the duty. The language used to state the terms, conditions or specific performances must express the true intent of the contract, for a doubt as to intent will invariably lead to evasions and dissension during its execution. The theory of the contract is to describe the undertaking from the physical condition of the property at the beginning, concisely stating the duties and work to be performed by the contractor, and the conditions that must be found to exist on the property at the termination of his work. Also a preamble, stating precisely what the function of the work to be carried out by the contractor is; in what way, manner, and at what times, he will receive payments for the work performed; when the work must be started, and when completed. A penalty cannot be imposed for a delay beyond the agreed time of completion of contract, unless a bonus is stipulated for completion prior to the time stated. It is hard to enforce a penalty, as the courts consider a punishment of this kind to be their exclusive prerogative. A penalty for damages that arise from the contractor's negligence or incapacity, can be inserted in a contract in the form of liquidated damages, and be withheld permanently from the total compensation, in case of any apparent default on the part of the contractor.

No portion of a contract requires greater experience and ability than the forecasting of all possible eventualities, that would materially affect the agreement, and to provide a proper solution for carrying out the terms of the contract, under each combination of circumstances that may arise.

Where the contractor, in the execution of his contract, is to be supplied with material by another contractor, or the company; both the time when these materials are to be delivered; where they are to be delivered; in what quantities; and to what specifications or conditions they are to conform; and whether the contractor, or company's engineer, is to verify the deliveries in regard to quantity and character must be specified. A definite line must be drawn as to where the responsibility of the company ends, and the contractor's begins.

The clauses regarding extras can only be made as stringent as the exactness of the preliminary engineering and specifications will admit. Excavations, foundations and filling in, the character of soil, and the proportion of rock to be removed, are (except in the case of a gross contract) generally considered on the basis of the cubic yard, multiplied by a constant which varies with the distance the refuse has to be moved for disposal. Whether the refuse is waste or fill, rock or earth, the unit prices are adjusted to cover the entire operation. Rocks which have to be blasted to be handled are allowed in the estimate as stone. In the case of foundations such as bridge abutments, where the character of the soil has not been previously determined, allowances are made for sub-surface depths, and are proportioned to surface construction costs.

The contract must indicate clearly what constitutes a failure to perform, and what lapses will be considered such a failure. What acts beyond the contractor's control will be considered essential in order to extend the time of completion; what natural conditions can arise on the property, or what lapses by other contractors, which will necessitate an extension of the time limitation; what information shall the engineer supply the contractor during the progress of the work, and when shall this information be given; what conditions can arise, and who will be the authority to decide, in the location of structural changes, the necessity of which have become evident in the progress of the work; how the contractor will be paid for such additional work, or, where there is a gross contract, how he will rebate to the company, if the changes cost less than the originally proposed route or method; what redress or damages the contractor will have when information or material is delayed, so that the continuous performance of the work on the contract cannot be carried on. All these points should be so clearly stipulated that no partial performance under the contract could be accepted as a complete satisfaction of the agreement or a compliance with the intent.

Where the contractor performs any portion of the engineering work and his contract also includes the purchase of material, the character, quantity and disposition of the latter should be distinctly stated; also the order in which the work is to be carried on; the time and character of inspections; under

whose authority these inspections are to be made; the form of notification of accepted, or rejected work; and by what authority rejections are made, should be stated.

In the case of differences arising under a contract or specification, the usual custom is that each party shall appoint a referee, these two appointing a third, and the decisions rendered by a majority of the three are mutually agreed to be binding upon both parties, and neither party shall seek any further action in a court of law.

The sealing and witnessing of a contract should preferably take place before a notary, and the bond, or character of security required from the contractor for the faithful performance of his duties is then submitted. On the part of the company, the guarantees of payment to the contractor are also required to be stated.

The above is a framework which should obtain in all contracts the details of which can be varied to meet the requirements of the different relations that may exist between a company, engineer and contractor. These relations should be of such a nature as to maintain the original intent established, and carry out the true meaning of the contract. This is the ideal function of a contract, but in the building of a railroad it frequently requires the exercise of both fairness and equity, on the part of all parties concerned, to harmonize the differences between the intent and criterion, of specific performances which may enter the contract, and may only become apparent during the course of construction. In the writing of a contract, terse, concise statements, and requirements, are more easy to fulfill, and the intent is more readily comprehended, than when certain phrased forms are introduced, which are often difficult of correct interpretation.

Specifications

The specifications for the construction of the road-bed are based on the data supplied by the surveys, maps, location stakes, monuments and rights of way, the engineer having this data before him. The first clause of the specifications of an electric railway covers the clearing of the right of way of all underbrush, trees, fences and movable surface obstructions. It is generally specified that the clearing is to be done between the

offsets established by the engineer, which may be blazed trees, stakes and other marks designated on the surveyor's map. In all cuts or fills not over two feet in depth, it is preferable to require all stumps to be torn up by their roots. When embankments are over three feet high, grubbing is not necessary, the trees and underbrush can be cut low, slightly below the surface of the surrounding soil. Before excavation or filling can begin it is also required that any accumulation of organic matter be removed from the surfaces. Where fills have to be made, grade stakes must be set by the engineer. The slope of cuts must be stated, also the slopes of embankments with different characters of soil. The usual slope for earth is one and a half horizontal to one vertical, for both excavations and fills. For damp clay and solid gravel, if protected from drainage water, slope one to one, but this cannot be permanently depended upon unless retained by vegetable growth. Fine sand and clay exuding moisture, may require a slope of one and three-quarters to one, and as much as two to one, and where quicksand, or easily washed or gullied earth, three and four to one. In rock work the slopes are generally one-quarter to one, and one-half to one for loose rock, and one to one for loose friable rock, which disintegrates and crumbles when exposed to the air. Rock embankments should stand one to one. The level of the sub-grade should be indicated, and the crowning required and the width of cut at sub-grade given. Rock cuts, especially if they include a curve, should be made wide enough to clear the car body in all positions, at least 18 inches, and in tunneling with overhead construction there should be 22 inches or more above the trolley board. The specifications should also state that the engineer will run test levels, verifying the positions of stakes and elevations, resetting any stakes that may have been displaced, and properly guard any important transit points and stations. He will also stake out the width of a cut on the surface and at sub-grade, the width of fills, base and top, the level of fills above grade line to allow for shrinkage.

The following shrinkage table is given for the guidance of the engineer:

TABLE IX

	Embankment.	Amount Required.
Sand and gravel	80 cu. yds.	87 cu. yds.
Clay	100 "	111 "
Loam	120 "	136 "
Wet soil	150 "	200 "
Rock, large fragments	600 "	375 "
" medium fragments	700 "	413 "
" small fragments	800 "	444 "

That is, 1,000 cubic yards of clay will only make about 900 cubic yards of embankment and it will require 1,111 cubic yards of excavation to make 1,000 yards of embankment. The reverse is true with rock, 1,000 cubic yards of medium-sized rock excavation will make 1,700 cubic yards of embankment, while 1,000 cubic yards of embankment will only require 587 cubic yards of excavation. In filling with rock, the largest size to be used in the fill should be stated. The slopes of the sub-grades for drainage, the ditching and the sub-surface drains, should be referred to and located on the map.

Specifications for culverts should state the method of their construction and location, their width and height and whether open or covered; specifying tile pipe, iron pipe, masonry or concrete.

In the cases where soft ground has been found, or quicksand, the method of piling, mattressing or bridging, should be detailed. In fills, the limiting height should be given. Where trestle-work must be substituted for fills; the character of foundations for the bents, whether piling can be used to form these bents, what will be the type of foundation in the case of bents on independent foundation, and the size and character of timber to be used, should be distinctly specified. A drawing of the proper framing for the different heights of construction required should be furnished giving the distance between centers of bents, the size of the stringer and the grade line of the stringer, and also the provision on the bents for the location of poles of the pole-line.

In the case of bridges, if the contractor is not required to supply the span, but to build the abutments only, the width of span, the character of material used in construction and the method of construction, the foundation area, the depth of foundation, the batter of the foundations, the top area of the

foundations, and the locations of the plates and bolts on which the bridge truss or beams are to rest, should be given. Twenty-foot spans and under are usually constructed of I-beams, or heavy timbers, provided with tension member rods. In a concrete arch give the spring of the arch, and the depth of concrete required for the crown of the arch. A span of from thirty-five to forty-five feet, may be either a large I-beam or girder construction, or a wooden truss.

CHAPTER III

RAILWAY TRACK CONSTRUCTION

Interurban Roads

Good ballast, with proper side ditches and the necessary tiled cross drains, and culverts, affords good drainage. Broken stone which will pass through a ring $1\frac{1}{2}$ inches in diameter, forms the best ballast after it has settled. Gravel is next best and cheaper, and settles somewhat quicker. The selection of the character of the ballast depends upon local conditions. Sometimes an abundance of stone is to be obtained along the right of way, in which case a stone crusher could be installed and sufficient ballast provided. At other times gravel banks are available and gravel can be obtained much cheaper than the stone. In either case the object desired is a good solid foundation for the track through which water can pass. In first-class construction from 8 inches to 12 inches of either stone or gravel should be laid on the sub-grade to form a solid foundation on which to lay the rails and ties; ballast should then be filled in to the top of the ties. In tamping ties a tamping bar should always be used, shovel tamping is not good practice. Ballast should be given a slight crown to allow water to flow off more readily. It should be even with the top of the tie in the center line of the track and from 2 inches to 3 inches below the top at the ends of the ties.

The importance of a good foundation for interurban track cannot be overestimated. Money invested in good ballast placed under the ties, and in the purchase of good ties, is a better investment than if it were invested in a heavier rail. A comparatively light rail on a good foundation is much better than a heavy rail on a poor foundation. Some have the idea that a heavy rail will assist a poor foundation, but this is not true.

The proper factors to be considered in determining the weight

of rail are the weight and speed of the cars, the size and spacing of the ties, and the kind of rail joint. For high speed cars not over 40 tons in weight, with good solid ties not less than 6 inches x 8 inches x 8 feet, spaced 2 feet on centers, the use of a 70-pound A. S. C. E. T-section of rail is good average practice. One of the several types of bridge joints with base plate

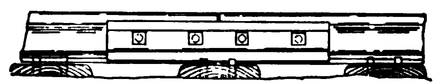


Fig. 2.—Supported Joint.

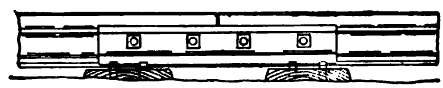


Fig. 3.—Suspended Joint.

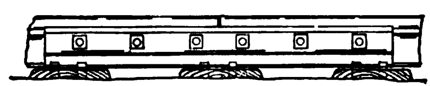


Fig. 4.—Supported Joint.

is the best joint if the expense seems warranted, otherwise the 4-bolt or 6-bolt standard angle plates, suspended and staggered. Figs. 2, 3 and 4 show the latter joints suspended and supported. Fig. 5 shows the section of the same standard joint

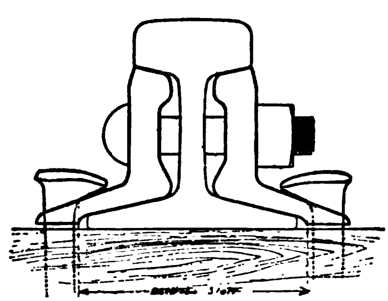


Fig. 5.—Section of Standard Joint.

with spikes driven through grooves in angle plates to prevent creeping track. The suspended joint is more generally used.

The size of the ties, 6 inches x 8 inches x 8 feet, is steam road standard, and while there are some interurban roads built

with ties as small as 5 inches x 6 inches x 7 feet, it is now acknowledged that no sizes smaller than the standard are satisfactory. The best kind of wood for ties depends on the locality and climate, but the kind usually employed is that which is most easily obtained. The cost of ties is continually advancing owing to the increasing scarcity of timber, and standard ties now cost from 50 to 70 cents each according to locality. The life of a tie is of great importance and depends upon the kind of wood, character of the ballast, and drainage. The following figures are for average conditions: Chestnut, 7 years; cedar, 12 to 16 years; white oak, 7 years; yellow pine, 5 years; hemlock, 3 to 6 years; mountain pine, 2 to 4 years. Cedar ties are usually only available in certain parts of the West and Northwest where they grow, for high freight charges added to their original cost would render them too expensive. In some localities the cheaper grades of pine ties have been treated by a creosote process which brings their cost up to about 70 cents, and increases their life to an average of 15 years. A considerable number of such treated ties are in use by both steam and electric roads. The steam roads, realizing the future importance of the tie question, have made many experiments with steel or iron ties, in order to determine their life. The question has hardly been settled yet, but the Pittsburg and Lake Erie (steam road) is said to have their entire line laid with steel ties. The spacing of ties depends on the weight of the rolling stock and on the weight of the rail. A fair figure for interurban work would be a space of two feet between centers, but with 18 inches between centers close to joints. This gives 16 or 17 ties per rail of 30 feet. Large numbers of long-leaf yellow pine ties from the South are used by some of the principal trunk lines in the North. Hewn ties are said to last longer than sawed, probably because the saw opens the wood fiber and renders it less impervious to moisture than when an axe is used.

The use of spring switches at sidings or turnouts in interurban lines is advocated by many. Some object to them because accidents have occurred due to springs becoming weakened, causing the car to split the switch when running against it. Careful inspection should remedy this trouble. They are widely used, and where sidings are comparatively long an ad-

vantage is that when cars are on time neither has to stop on passing. The Detroit, Munroe & Toledo is so equipped and with sidings about a mile long. This is unusual but good practice. Stub end sidings with locked switches are safest, because the waiting car must back out, after the other car has passed, and reset the switch for the main line. This plan is advisable at sidings which are not regular schedule meeting points. All curves which are not of very long radius should have guard rails next to the inside rail of the curve, if it is desired to take these curves at speed. Short bridges are usually of the concrete arch type, or the steel plate girder type with concrete abutments. Longer bridges are of the usual steel truss type. Bridge building is a science by itself and few electric roads attempt to design their own.

The following simple rules for the use of roadmasters may be of interest:

To find the gross tons of steel rails per mile, multiply the weight of the rail per yard by 11 and divide by 7.

To find the radius of any curve in feet, divide 5730 by the degree of the curve.

A steel rail 30 feet long expands $\frac{1}{4}$ inch for a rise of 100° Fahrenheit in temperature.

Some roads on laying rails, allow the following space between

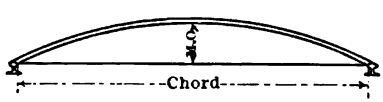


Fig. 6.—Construction for Finding Degree of Curve.

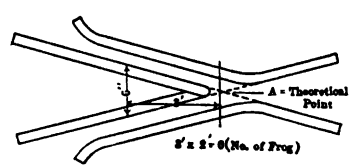


Fig. 7.—Construction for Finding Number of Frog.

rail ends: At 0°, space should be $\frac{1}{4}$ inch; at 25° F. above zero, space should be $\frac{3}{16}$ inch; at 50° above, $\frac{1}{8}$ inch; at 75° above $\frac{1}{16}$ inch; at 100° above, no space. Expansion should always be uniform. By observing this and using care in placing joint plates, and in spiking, much can be done to stop "creeping track."

To find the degree of any curve (Fig. 6): Find the middle ordinate, M. O., of a chord 61 feet 4 inches long. The number of inches in this middle ordinate is the degree of the curve.

To find the middle ordinate of a 30-foot rail, divide the degree of the curve by 4. This is good up to ten degrees.

To find the number of a frog (Fig. 7): Measure the distance in feet from the theoretical point of the frog to where the gauge lines are 6 inches apart. Multiply this distance by 2. The result is the number of the frog.

To find the number of a frog for any turnout (Fig. 8): Lay out the line of lead A. B. Mark where it crosses gauge line of rail. Measure the distance in feet from this point to where this line is 6 inches from the gauge side of rail. Multiply this

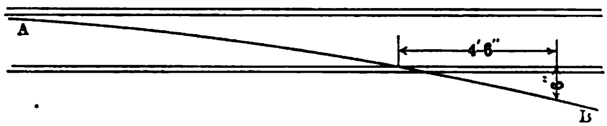


FIG. 8.—Construction for Finding Number of Frog for Turnout.

distance by 2. The result is the number of the frog required. In Fig. 8, the distance shown is 4 feet 6 inches. The number of the frog is therefore No. 9.

The rule for the theoretical lead of a split switch for any gauge is: Twice the gauge of the track multiplied by the num-

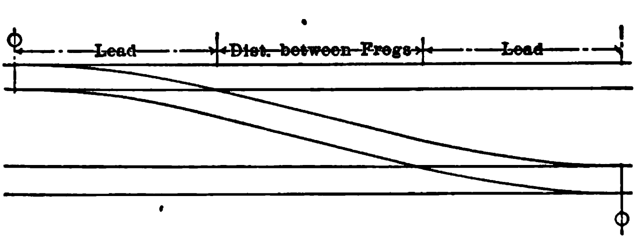


FIG. 9.—Construction for Laying out Crossover or Turnout.

ber of the frog; or for 4-foot $8\frac{1}{2}$-inch—and 4-foot 9-inch—gauges the lead is $9\frac{1}{2}$ times the number of the frog. But in practice the rule makes the leads too long. For shortened leads which will be found to work well in practice, the following rule may be used: For 4-foot $8\frac{1}{2}$-inch gauge the lead for all the frogs up to and including a No. 6, is $9\frac{1}{2}$ times the number

of the frog; for Nos. 7 and 8, 9 times the number of the frog; for Nos. 9 and 10, 8½ times the number of the frog; and for all above No. 10, 8 times the number of the frog.

The rule works out as follows:

To lay out a crossover or turnout (Fig. 9):

Table X

For 4-foot 8½-inch Gauge.

No. of Frog.	Length of Lead.
6	57 feet
7	63 "
8	72 "
9	76 " 6 inches
10	85 "
11	88 "
12	96 "
15	120 "

These shortened leads may be varied from the above when desirable to do so, to avoid waste of rail by cutting, or to suit the material at hand.

Table XI

4-foot 8½-inch Gauge.

No. of Frog.	Length of Lead.		Distance between Frog Points. Track Centers. 11 Ft.		12 Ft.		13 Ft.		14 Ft.		15 Ft.		16 Ft.		Length of Lead.	
	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.
6	56	6	9	6	15	6	21	6	27	6	33	6	39	6	56	6
7	65	11	11		18		25		32		39		46		65	11
8	75	4	12	8	20	8	28	8	36	8	44	8	52	8	75	4
9	84	9	14	3	23	3	32	3	41	3	50	3	59	3	84	9
10	94	2	15	10	25	10	35	10	45	10	55	10	65	10	94	2
11	103	7	17	5	28	5	39	5	50	5	61	5	72	5	103	7
12	113	0	19		31		43		55		67		79		113	0
15	141	3	23	9	38	9	53	9	68	9	83	9	98	9	141	3

Table XII

MIDDLE ORDINATES FOR BENDING RAILS FOR CURVES

Length of rail 30 feet.

Curvature. Deg.	Min.	Radius. Feet.	Middle Ordinate. Inches.
	20	17189	.08
	40	8594	.16
1	0	5730	.24
1	20	4297	.31
1	40	3438	.39
2	0	2865	.47
2	20	2456	.55
2	40	2149	.63
3	0	1910	.71
3	20	1719	.78
3	40	1563	.86
4	0	1433	.94
4	20	1323	1.02
4	40	1228	1.10
5		1146	1.18
6		955.3	1.41
7		819	1.65
8		716.8	1.88
9		637.3	2.12
10		573.7	2.36
11		521.7	2.59
12		478.3	2.83
13		441.7	3.05
14		410.3	3.30
15		383.1	3.54
16		359.3	3.76
18		319.6	4.21
20		287.9	4.70

Table XIII

TABLE OF CUBIC YARDS OF BALLAST PER MILE OF ROAD. SIDE SLOPE OF BALLAST 1 TO 1. WIDTH IN CLEAR, BETWEEN TWO TRACKS 6 FEET

Total Depth	Top Width, Single Track.			Top Width, Double Track.		
Inches	10 Feet.	11 Feet.	12 Feet.	10 Feet.	11 Feet.	12 Feet.
12	1759	1947	2143	3503	3699	3895
18	2974	3267	3560	5800	6094	6388
24	4294	4685	5074	8196	8588	8980
30	5711	6200	6687	10690	11180	11670

Note: Total depth of ballast is from top of tie to sub-grade.

Track Construction Costs

The cost of interurban track construction varies greatly due to the material used, and the character of the right of way.

The following figures are of course subject to variation in different sections of the country, but as an average they represent what the work referred to has cost in the Middle West.

Grading.—With 1,000 feet haul and 16 cubic feet wheelers, earth should be moved for from 15 to 18 cents per cubic yard. Add five per cent. for each 100 feet over 1,000 feet haul.

Handling ties.—Cost of handling ties with teams, haul not exceeding three miles, 3 cents per tie.

Handling steel.—Cost of unloading steel rails off cars from mill and stacking them by hand 25 to 30 cents per gross ton. Cost of loading steel on cars for track laying, 30 cents per ton. Steel rails should be handled, under the most difficult circumstances, for 70 cents per ton including unloading and reloading and hauling to track layers with a steam locomotive.

A mile of track should be laid complete for $250.00 including the placing of ties on grade at two-foot centers. Regular contract price for handling steel, unloading, reloading and hauling is 70 to 80 cents per ton; handling ties three cents to five cents per tie depending on size and length of haul; laying steel $300.00 to $350.00 per mile.

Bonding.—Drilling rail, 60-foot lengths can be done for 50 cents per gross ton, but regular contractor's price is $1.00. Bonding labor will cost approximately $60.00 per mile, 176 joints.

Ballasting.—The cost of handling gravel from pits, loading with steam-shovel, and hauling to dump with steam locomotive, longest haul not to exceed 10 miles, should not exceed 10 cents per cubic yard. This includes labor of gravel pit crew, steam shovel and locomotive crews. Labor for ballasting and surfacing track should not exceed $400.00 per mile. This figure is for a 6-inch rise, or 1,250 cubic yards of ballast per mile. The contract price for this work usually averages $800.00 to $1,000.00 per mile.

Pole line for trolley.—Setting poles 6½ feet deep in sand or clay should cost 75 to 80 cents per pole. In quicksand soil at

least 25 per cent. must be added to the above as it is then necessary to use barrels which increase the cost greatly.

An average cost in detail for comparatively level country, with a number of cuts and fills, may be assumed to be as follows:

Grading	$2,200.00
Rock ballast	2,500.00
Ties	1,500.00
70 lb. steel rails, 110 tons at $30	3,300.00
Joint plates, bolts and spikes	600.00
Bonds	400.00
Labor, laying steel and ballasting	1,000.00
Fencing	500.00
	$12,000.00

The above costs represent a fairly well built railroad. The cost of bridges, abutments and culverts is omitted because it

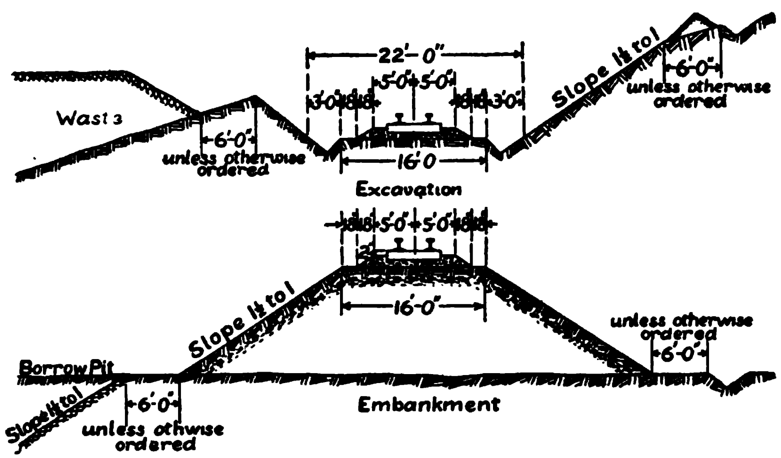


FIG. 10.—Average Rail Section for Interurban Road.

is not considered feasible to attempt to assume average conditions in these items. But the cost of grading is placed high, as is that of ballasting, and it may be assumed that these items cover the former except under unusual conditions.

That many so-called interurban roads have been built for considerably less is well known. By the use of gravel ballast, cheaper ties, heavier grades and 60-pound steel it is not difficult to cut off $3,000.00 from this estimate. In every case this

course will result in an increased maintenance cost, and if not properly maintained entire rebuilding may become necessary. The cost of the right of way is too variable to be considered. In the vicinity of the large cities it may be very high, from $100.00 per acre up, while in the farming districts it is often donated by the land owners.

Fig. 10 shows good average earth sections for a single track interurban road.

Rails and Joints

The proper section and weight of rails to be used by electric railways has been a perplexing question from the beginning. On the interurban lines little or no difficulty has been experienced, for in most cases they are permitted by the authorities

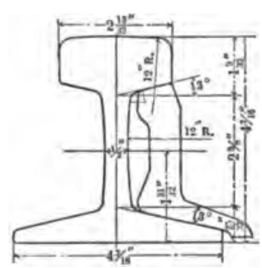


Fig. 11.—A. S. C. E. Standard T-Rail Section.

to use the standard T-rail section such as is used by all steam roads. Fig. 11 shows the standard T-rail section recommended by the American Society of Civil Engineers. This section is used by interurban roads up to a weight of 80 or 85 pounds per yard, and a height of 5¾ inches. Most of the large steam roads have their own standard section, few of which differ but slightly from this. But the trouble encountered in city track construction, in nearly every city, has been caused by the city authorities not only refusing to allow the T-rail to be used, but in specifying the style of section they would approve. The city engineers desired a rail which would offer no obstruction to, or be in any way detrimental to vehicular traffic, and which would best preserve the pavement. Many cities early decided that the T-rail did not meet these requirements. The rail was too low, being from 4½ to 5 inches high,

and where vehicles followed the track their wheels cut away the pavement close to the rail, and as the rail head had to project an inch at least above the pavement to allow room for the car wheel flange, this made it inconvenient for vehicles crossing the track, especially at an angle. The lack of height made paving very inconvenient as the blocks were usually deeper than the rail.

All this caused the design of the various types in use to-day, some of which are allowed in one city, and others in another. As the weight of cars increased, the weight and height of the

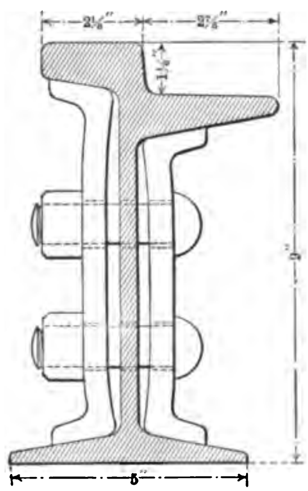


FIG. 12.—Nine-Inch 94-lb. Girder Tram Rail.

various girder rails has had to keep pace. The weight now most in use in cities will vary from 70 pounds per yard to 137 pounds, and the standard height can be said to be 7 inches and 9 inches. Fig. 12 shows a section of a 9-inch girder tram rail weighing 94 pounds per yard. It is said that this rail is well adapted to a street where the traffic follows the track. Fig. 13 is a form of grooved girder rail known as the "Trilby" because of its footlike shape. This rail was designed by the engineers of the New York City Street Railway, and in a slightly modified form is still used by them. It is now quite extensively in use. Fig. 14 shows the center bearing type of rail. It is said

that Kansas City is now the only city in which this is permitted to be the standard section. From a railroad point of view it is the best rail except the T for use in cities. Fig. 15 shows one of the latest developments of the T-section used in

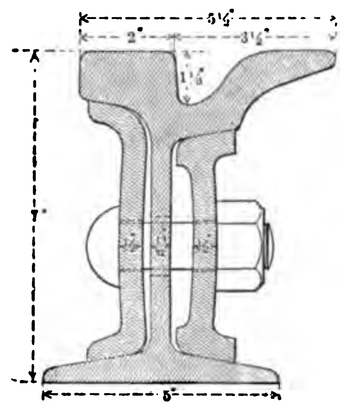


FIG. 13.—"Trilby" Rail.

Milwaukee, in paved streets. It is 7 inches high and weighs about 90 pounds per yard.

In a number of cases in the past, the use of the T-rail in a

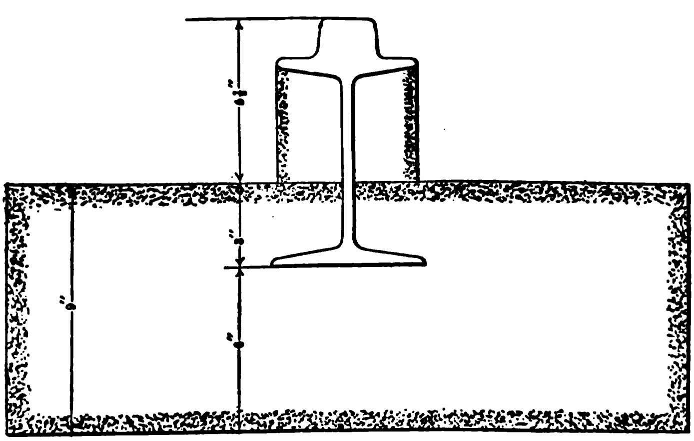


FIG. 14.—Center Bearing Rail.

paved street has resulted in failure due to the vehicular traffic cutting grooves in the pavement just inside the gauge line.

This caused a dangerous condition for vehicles, and the railway company was at constant expense repairing pavement. While a T-rail construction will not afford an inducement for vehicles to follow the track, the damage has occurred on those streets where large numbers of heavy trucks are compelled to follow the track. When the tram, or grooved girder rail is adopted, the trucks and other vehicles are attracted, for the gauge of their wheels is usually such that they roll on the tram or groove of the rail, and thus save the pavement. But the use of a rail which attracts vehicular traffic is always an objection on account of the delays which it causes to cars. Other reasons there are, of even greater import, why the rail-

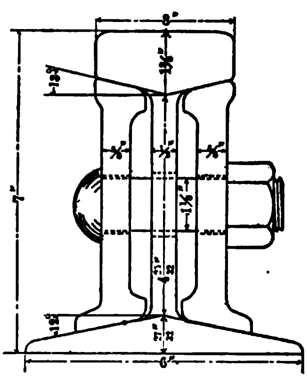


FIG. 15.—T-Rail Used in Milwaukee.

way company should use the T-rail when permitted. The life that it is possible to obtain from the T-rail is much greater than could ever be obtained from the girder, now that joints no longer limit the life of either. With deeper flanges of interurban car wheels rapidly coming into use, but little wear of the rail head of the tram or grooved girder can take place before the cars are running on the wheel flanges, and this latter situation has now become quite common.

The amount of wear that can take place on the T-rail before the track is worn out is independent of the wheel flanges. Of recent years the design of the high or so-called "Shanghai" T-rail, together with greatly improved methods of paving and track foundations, has resulted in a construction presenting a smooth street surface for vehicles which is practically as good

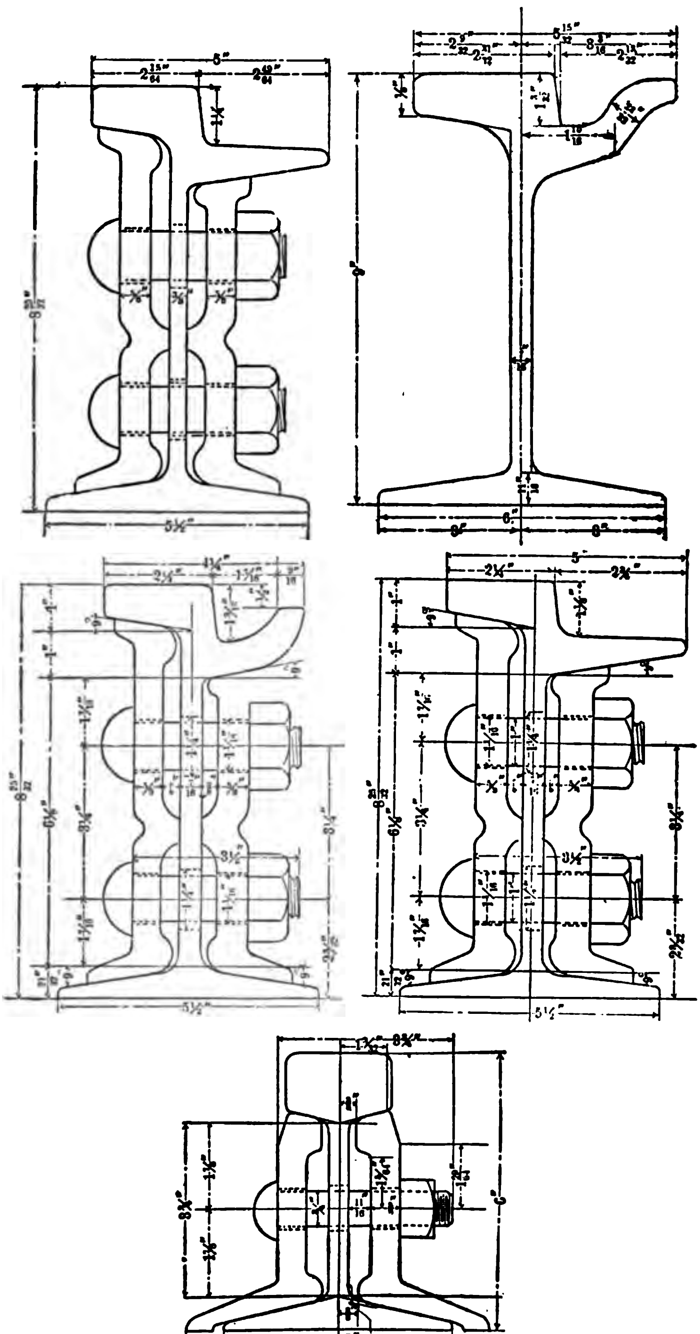


Fig. 16.

as the grooved rail, and has the advantage that the groove will never clog with ice or dirt. The stronger pavements now used

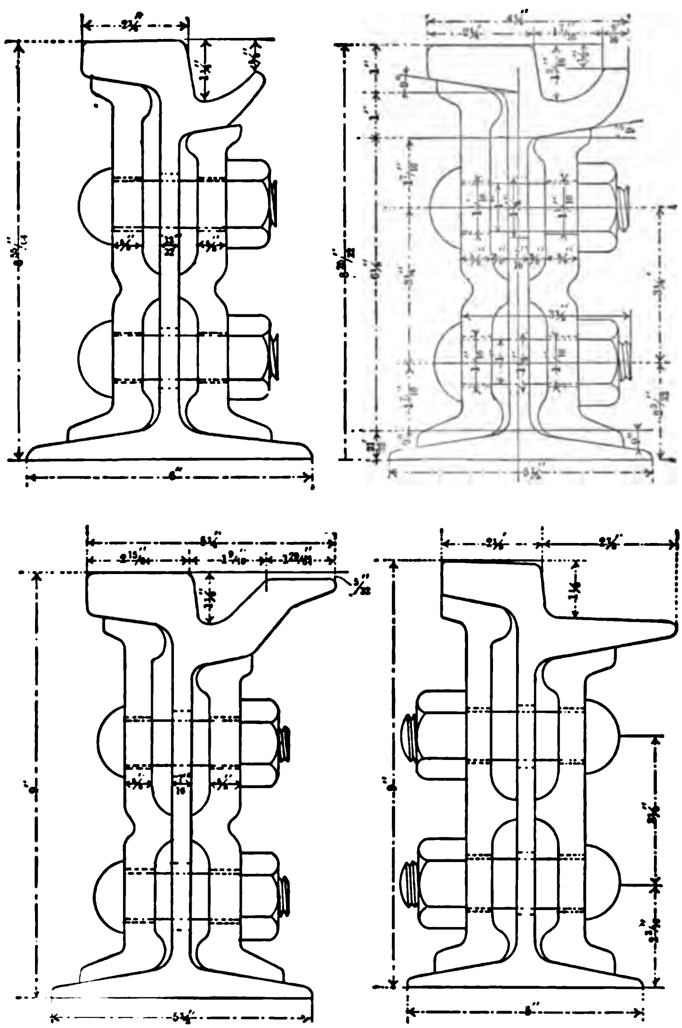


FIG. 17.

hold up well under vehicles when compelled to follow the track, but its tendency to drive the traffic to the side of the street, where well paved, is of great advantage to the operation of the cars. This construction has been so successful, both from the

point of view of the city, as well as the railway company, that it is now being adopted as standard for paved streets in many

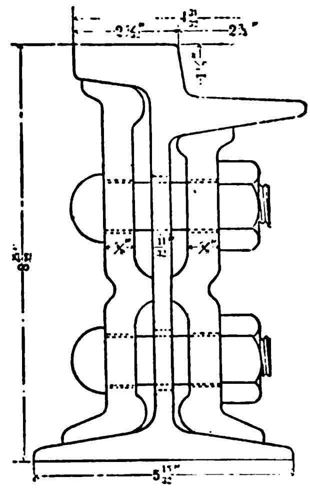


FIG. 18.

of our largest cities. The construction is described in detail in another chapter.

Table XIV gives the dimensions of the standard rails used in paved streets in the cities named.

The 9-inch Trilby grooved girder rail (Fig. 19), the standard

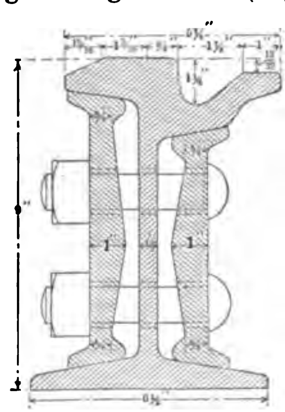


FIG. 19.—"Trilby" Rail Used in Philadelphia.

in Philadelphia, weighs 137 pounds per yard, one of the heaviest sections yet rolled for street railway construction. The

City of Denver has always used a T-rail. It was adopted some years ago by Milwaukee, St. Paul, Minneapolis and other cities, after an unsatisfactory experience with other types, and it is continually growing in popularity.

The best composition of steel from which rails are rolled has

TABLE XIV

TRACK CONSTRUCTION IN PAVED STREETS IN FOURTEEN CITIES OF THE UNITED STATES

CITY AND NAME OF COMPANY	Kind of Rail for Paved Streets	Kind of Joints	Manner of Supporting Track—Ties or Concrete Stringers	Manner of Holding Rails to Gauge	What Bed Under Ties	What Bed Around Ties
Baltimore—United Railways & Electric Co.	Grooved	Angle bar (8 bolts)	Ties 6 in. x 8 in. x 8 ft.	Tie rods 6 ft. apart	Sand	Sand
Boston Elevated Railway Co.	Grooved	Angle bar (12 bolts)	Ties 6 in. x 8 in. x 6 ft. 6 in.	Tie rods	Gravel	Concrete
Buffalo Railway Co.......	Grooved	Electric welded	Concrete bed & concrete stringers	Ties 5 ft. apart	Concrete	Concrete
Chicago City Railway Co...	Girder	Cast welded	Ties 6 in. x 8 in. x 8 ft.	Brace tie plates	Gravel	Gravel
Cleveland Electric Railway Co.......	Grooved	Cast welded & 12-bolt angle bars	Ties 5 in. x 8 in. and 5 in. x 7 in.	....	Concrete	Concrete
Denver City Tramway Co..	Shanghai T	4-bolt angle bars	Ties 6 in. x 8 in. by 6 ft. 6 in.	Tie rods	Gravel	Concrete
Detroit—United Railway..	Grooved	Continuous	Concrete stringers	Ties 30 ins. apart	Concrete	Concrete
Indianapolis Traction & Terminal Co..	Girder and new Shanghai T	Continuous	Ties 6 in. x 8 in. x 7 ft.	Tie rods	Concrete	Concrete
Milwaukee Electric Railway & Light Co.	New Shanghai T	Cast welded	Ties 6 in. x 8 in. x 6 ft. 6 in.	Ties	Concrete	Concrete
Minneapolis — Twin City Rapid Transit Co............	Shanghai T	Cast welded	Concrete stringers	Tie rods 10 ft. apart	....	....
Philadelphia Rapid Transit Co.	Grooved	Zinc	Concrete stringers	Special chair and tie rod	....	....
Pittsburg Railways Co.	Grooved	Cast welded	Ties 6 in. x 8 in. x 8 ft.	Tie rods	Broken stone	Broken stone
San Francisco—United Railroads	Girder	Cast weld	Ties 6 in. x 8 in. x 8 ft.	....	Concrete (bitumen paving), Broken stone (block paving)	Concrete, Broken stone
St. Louis Transit Co...	Grooved	Angle bar and continuous	Concrete stringer	Dupont tie rod	... .	....

been a subject of considerable study by railway companies as well as by the steel mills. A tough, fibrous steel, not too hard, is the best, and the different compositions specified by the principal railways are very similar. The following specifications as to the analysis are adopted by the railway companies in the cities named.

TABLE XV

RAIL COMPOSITION SPECIFIED IN BOSTON

	Per cent.		Per cent.
Carbon	.50	to	.60
Manganese	.80		1.00
Sulphur not to exceed			.08
Phosphorus not to exceed			.08
Silicon	.10		.15

Rails containing carbon below 50 or above 62 per cent. will be rejected. Steel for rails to be made by the Bessemer process.

BUFFALO

	Per cent.		Per cent.
Carbon	.48	to	.58
Phosphorus, not to exceed			.10
Silicon, not to exceed			.20
Manganese	.80		1.10

DENVER

Carbon	.46	.56
Phosphorus	.10	or less
Silicon	.10	or over

PHILADELPHIA

Carbon	.45	.55
Phosphorus, not over		.10
Silicon		.20
Manganese	.80	1.00

SAN FRANCISCO

(For light rails under 70 lbs.)

Carbon	.38	.48
Phosphorus, not to exceed		.10
Silicon, not to exceed		.20
Manganese	.70	1.00

(For rails weighing 90 lbs. to 100 lbs.)

Carbon	.45	.55
Phosphorus, not to exceed		.10
Silicon, not to exceed		.20
Manganese	.80	1.00

In Philadelphia it is said that the life of a girder rail, under the heaviest traffic conditions, is not over ten years. This is

about that found in other cities under equally severe conditions. In New York the life of the special work at such junction points as experience the heaviest traffic has been about five years, but more recently the use of frogs and switches with hardened centers has probably increased their life.

One of the hardest questions to decide is the weight of rail to use, and in no part of the construction of the road will a mistake in judgment react so heavily in track maintenance charges. The selection of too light a rail for the traffic and weight of equipment, will prove an extravagant economy. The cost of rails is the largest single item that enters into the track material, but to put down too light a rail will increase maintenance cost and reduce the possible maximum schedule at which it is safe to operate.

The three elements involved in the rail, are its stiffness, strength and cost. The following relations between stiffness, strength and cost have been established, and from an analysis of them, we can find how much stiffness, and how much strength, we can buy for one dollar.

The strength of a rail varies as the square root of the cube of its weight. The stiffness varies as the square of its weight. As the stiffness increases, the area over which the equipment weight is distributed is increased, the disturbing action on the ballast is reduced and the rail maintains its own alignment. This gives a smoother running road, and consequently a lower coefficient of friction per ton moved over the road. The expansion of heavier rails with increasing temperatures is apparently less than that of light rails, and smaller spaces can be safely permitted without buckling the track. It is generally conceded that the reason for this is that its temperature rising at a slower rate, there is time to equalize the strain along its length, and consequently its cross-section changes instead of all the expansion taking place in its length. This is especially true where a rail is imbedded in concrete and surrounded by paving, for then all of its expansion takes place in its cross-section and none in its length.

In Table XVI, column (4), will be found the comparative stiffness in weights of rails varying from 35 to 130 pounds, in column (5) the cost per unit stiffness, in column (6) the comparative value received for the expenditure of one dollar;

column (7) gives the comparative strength for different weights of rails, column (8) the cost per unit strength, and column (9) the comparative strength bought for one dollar.

It is evident on examining this table that where track stability is to be purchased, a heavier rail will give a greater return for one dollar than the lighter sections, and the additional dollar spent for stiffness and strength in the first cost, will earn greater revenue than any stability gained by continual tamping and aligning.

TABLE XVI

ANALYSIS OF THE COST OF RAILS

1	2	3	4	5	6	7	8	9
Wt. of Rails, lbs. per yd.	2 Rails. Tons per mile, 2240 lbs.	Cost per mile at $30.00 per ton.	Comparative Stiffness.	Cost per unit of Stiffness	Comparative value rec'd for $1.00.	Comparative Strength.	Cost per unit of Strength.	Comparative value rec'd for $1.00.
35	56	$1680	.49	$3,429	$ .70	.586	$2,870	83.6 cts.
40	64	1920	.64	3,000	.80	.716	2,684	89.4 "
45	72	2160	.81	2,667	.90	.854	2,530	94.8 "
50	80	2400	1.00	2,400	1 00	1.000	2,400	100.0 "
55	88	2640	1.21	2,182	1.10	1.154	2,288	104.9 "
60	96	2880	1.44	2.000	1.20	1.314	2,191	109.5 "
65	104	3120	1.69	1,846	1.30	1.482	2,105	114.0 "
70	112	3360	1.96	1,714	1.40	1.656	2,028	118.3 "
75	120	3600	2.25	1,600	1.50	1.838	1,959	122.5 "
80	128	3840	2.56	1,500	1.60	2.983	1,897	126.5 "
85	136	4080	2.88	1,416	1.70	2.150	1,866	128.6 "
90	144	4320	3.24	1,323	1.80	2.301	1,836	130.6 "
95	152	4560	3.61	1,260	1.90	2.466	1,802	132.0 "
100	160	4800	4.00	1,200	2 00	2.634	1,798	133.5 "
105	168	5040	4.41	1,183	2.10	2.798	1,781	134.4 "
110	176	5280	4.84	1,090	2.20	2.954	1,760	136.1 "
115	184	5520	5.29	1,045	2.30	3.120	1,751	136.9 "
120	192	5760	5.76	1,000	2.40	3.282	1,748	137.1 "
125	200	6000	6.25	960	2.50	3.521	1,741	137.8 "
130	208	6240	6.76	923	2.60	3.601	1,732	138.5 "

The terms, light and heavy rail, are relative terms, and in 1890 a 40-pound rail would be called light, 50 medium and 60 heavy when applied to electric roads. In 1895, 45 would be called light, 60 medium and 72 heavy. In 1900, 60 to 70 were the average weights of rails used in good construction. In 1905, 60 was the light rail and the heavy rails have gone up to 137 pounds in city construction. These figures

clearly demonstrate the evolution of practice in regard to the purchase of stiffness and strength, as against track maintenance.

The recently constructed interurban roads are using rails varying from 60 to 90 pounds depending upon the weight and speed of equipment, and the character of the road-bed. The 70-pound rail is the average practice with a 50,000-pound equipment, with a schedule speed of 20 miles an hour, and a maximum speed of 40 miles; and the 74-pound section is being extensively used by roads having a scheduled speed of 30 miles per hour, and a maximum of 50 miles. Eighty to ninety pounds is the weight used where 60 miles per hour is the maximum speed attained.

Many roads are now suffering from a short-sighted policy in using the light rail, and about the only solution for this dilemma is to relay the whole track with a rail the weight and cost of which will decrease the maintenance charges by an amount sufficient to make the new investment profitable.

More recently the interurban roads have realized the importance of good ballast and have found that a heavy rail laid on insufficient ballast is almost as bad as a rail ordinarily considered too light. One manager of a well-known interurban road has stated that, within reasonable limits, good ballast is as important as weight of rail, and that good service can always be obtained from a comparatively light rail if well ballasted. It only goes to show how careful the engineer must be in order that expenditures should be so distributed as to get the most economical result, for it is as easy to buy too heavy a rail and no ballast, as it is a light rail and rock ballast.

The question as to whether rails 60 feet in length are to be preferred to those 30 feet long cannot be said to have been finally decided.

The principal advantage of the 60-foot rail is that it halves the number of joints, which produces a smoother running track, gives an improved conductivity due to the less number of joints to be bonded, and saves expense of both joints and bonds. Its disadvantage is its liability to expand and buckle slightly, thus throwing out the gauge of the track. It has been used with varying results. It cannot be said to be successful where it is entirely above ground and subjected to all the changes in

temperature and the rays of the sun. Much trouble has been experienced with it under these conditions. In paved streets, however, where it is below the surface of the pavement it is not subjected to the extremes of heat and cold, and while there have been failures in this case, there are also many examples of its successful use. This is especially true where the rails are laid in a modern pavement, strongly tied together and imbedded in concrete.

The sections of track which have been found to give the best results are those which have been laid when at or near the maximum temperature that they would attain, and the joints laid abutting together, which makes the gap at other temperatures the minimum. There is less liability of a 60-foot rail creeping than a 30-foot. Recently there have been some compromises where a 40- or 45-foot rail has been used, and also experiments with a light rail cast welded in 500-foot lengths, with slip joints every 500 feet. The latter was tested three years after it was laid down, and less than one per cent. of the joints were found broken.

Considered as a conductor, manganese increases the resistance of the rail, and .29 of one per cent. manganese will reduce the copper equivalent of a rail from 1,000,000 c. m. to 790,000 c. m. High manganese rails used near power stations, or having a high current density, can often be profitably supplemented by copper ground return conductors in order to reduce the total potential drop. In damp places and tunnels high manganese rails show greater depreciation from rust than normal steel rails.

It is usual in specifications for rails to stipulate certain restricting limitations in regard to the general dimensions and the method of manufacture, especially with regard to the finishing passes through the rolls. The rails should only pass through the rolls for finishing when they have reached a uniform temperature. The specification generally cites how many rails under length, and how many rails over length, and how many in each case will be accepted per each hundred tons. In order to limit the cross-section dimensions, the dimensions of the head, web and foot of the rail are determined by the variation of dimensions found in any one rail, and the variations found between any rails delivered under the same contract.

The straightening of the rails, and a clause to prevent the mills from rushing the metal through the rolls, or "squirting it through," as rapid rolling is called, should be included. The limitations as to cross-sections will prevent the mills using rolls after they are worn too much to produce a rail within the specified limitations. The above clauses in the specifications are essential, for the careful handling of the rails in the rolls increases their life and toughness, and the adherence of the rails to the cross-section dimensions gives a better fit to the bearing surface of the angle plate, thus holding the joints in better alignment.

Steam roads have obtained a guarantee of five years on the rails delivered by the mills, both in regard to wear and breakage. Electric roads, in some cases, have obtained the same concessions.

It is often customary to furnish a print with the specifications showing the location and drilling of the bolt holes for the fish-plate bolts. A punched hole increases the liability of the rail to fracture at the joint in service, and is not considered good practice. The size and location of the bond terminal holes is also sometimes specified. These holes should be bored at least $\frac{1}{32}$ of an inch smaller than the shank of the bond to be used to allow for reaming and cleaning the contact surface. In city work the location of the tie rod holes is also specified, but the punching of the foot of the rail for receiving the spike to prevent creeping has been discontinued, and is considered bad practice.

Formerly the life of rails on both steam and electric roads was limited by the life of the joints. This is true to-day to a great extent on steam roads, and to a lesser extent on street railways. It is due to the instability of the joint itself, and to the insecure foundation under the joint. In time the traffic loosens the joint, and the pounding of the wheels unsettles the ballast under the ties near the joint, and causes "low joints," which, if allowed to continue in this condition, results in the ends of the rail head becoming battered, so that no raising of the ends by tamping beneath the ties can bring them back to their former condition. The life of the rails is thus ended, though some roads utilize the rails further by cutting them off back of the bolt holes and redrilling.

T-rails on interurban roads are ordinarily joined by the usual 4-bolt, or 6-bolt, angle splice bars. These are usually laid suspended, that is with a tie under each end of the joint, but none directly under the break in the rail. To give a long life the nuts must be frequently tightened, as is always done on steam roads, but often neglected by interurban roads. In paved streets joints formerly gave much trouble because of the difficulty in getting access to the joints to tighten them, and

FIG. 20.—Bolted Joints with Splice Bars.

it became imperative to design a joint which would remain in proper condition without attention throughout the life of the rail. The depth of the heavy girder rails made it possible to design a bolted joint with splice bars, which, combined with a concrete foundation beneath the ties, accomplishes the result desired. Fig. 20 shows this joint.

The joint is frequently the weakest point in interurban track construction, and the life of a rail depends largely on, and is

FIG. 21.—Atlas Joint.

sometimes limited by the character of the rail joint. This difficult mechanical problem has been met in many ways, and gives quite a variety of choice as to what is the best joint to use under given track conditions.

As the rail has to move in reference to its splice bar in ex-

posed track, due to expansion and contraction, either the hole in the fish-plate has to be elongated parallel to the length of the rail, as in ordinary practice, or the hole in the rail has to be made larger to provide for this change. In some of the best track recently laid the fish-plates were drilled with a hole in which the bolt could be inserted with a light tap of a hammer,

FIG. 22.—Continuous Rail Joint.

the clearance being given in the hole of the rail to allow for the expansive movement. This construction has been found valuable especially in laying rails on bridges, to prevent creeping, where it is especially liable to happen, and also prevents

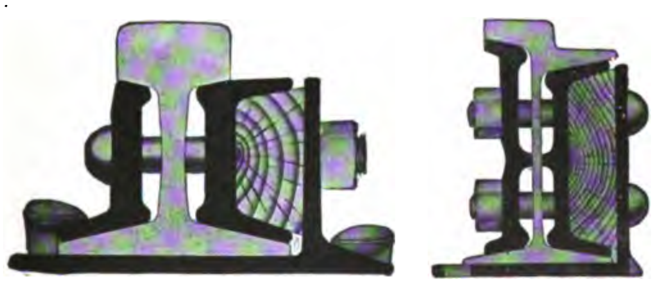


FIG. 23.—Weber Joint.

strains being thrown on the bridge. Splice bars, when they are punched, are often found to be out of true, and they should be specified straight, for the efficiency of the joint depends upon their being in contact along their whole bearing surface.

There are a number of patented joints in use designed to give rigidity to the joint, which have been very successful and

are widely used, both for steam and electric roads. The Atlas joint (Fig. 21) has bolts passing underneath the webs between the side and foot of the joint. The continuous rail joint (Fig. 22) has the support provided by an ordinary fish-plate, and also lips extending underneath the rail, and in intimate contact with the bottom of the base of the rail, and where these joints have been designed to fit the section of the rail used, they have given excellent service both on exposed rail and in pavement. The Weber joint (Fig. 23) combines both the fish-plate construction and an angle base plate through which the fish-plate bolts pass, a cushion of hard wood being used as a filler between the inside of the angle bar and the rail. Both the last two joints have been used extensively in steam and electric road practice.

City Roads

Track construction in streets provided with modern improved pavements has passed through many changes necessitated by the increase in traffic and weight of the cars during the past ten years. Not only have rails increased in weight, but it has been realized that the most important problem is a proper foundation. Perhaps ten years ago if the cost of the present construction in many of our large cities had been mentioned, it would have been thought out of the question. But experience has proved that to obtain good results and a reasonable life, expense must be incurred.

At one time sheet asphalt pavements were laid on a gravel or sand foundation; the result was a life of not over five years. Now with six inches or more of concrete beneath it the pavement lasts three or four times as long under average conditions. The same thing applies to the foundation for the track irrespective of the type of pavement.

In most cities the railway company is required to pay the cost of and maintain the pavement included in the space occupied by their tracks, and about two feet outside. The maintenance of track and pavement is thus combined, and it becomes a problem in economics to provide a structure which is as permanent as experience renders possible.

This has led in many cases to the adoption of the so-called concrete beam construction. In this method wooden ties are

sometimes used only to hold the track to gauge. That is, they are spaced 10 or 12 feet apart and provided with braces or chairs to hold the rails. The load is carried on a continuous beam or girder of concrete immediately beneath each rail and in contact with it. In some instances these beams have given trouble by breaking due to lack of strength where the earth has given away under them. But various expedients for stiffening the beams have been employed and by making them of sufficient size excellent results have been obtained. It is perhaps too early to say what the life of this construction should be, but it is thought to be fully equal to that of the rail.

The following illustrations with accompanying explanation show current practice in some of the largest cities.

Fig. 24 shows the construction now in use in Indianapolis, Ind. Wooden ties are spaced 12 feet apart. The concrete

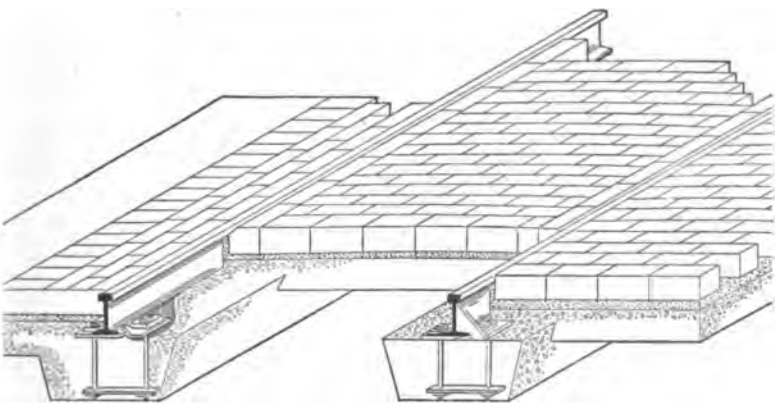


FIG. 24 —Track Construction Used in Indianapolis.

beams for supporting the rail extend about 11 inches below the base of the rail and are 18 inches wide at the base. The peculiarity of this construction lies in the anchor bolts holding the tie plates for the purpose of preventing the rails from kicking up under the traffic. The pavement here shown is brick or concrete.

In recent construction in Cincinnati, Ohio, the trenches were taken out 18 inches below grade, and nine inches of concrete was tamped under the base of the rail. The form of girder was that of a longitudinal truncated pyramid, 18 inches wide

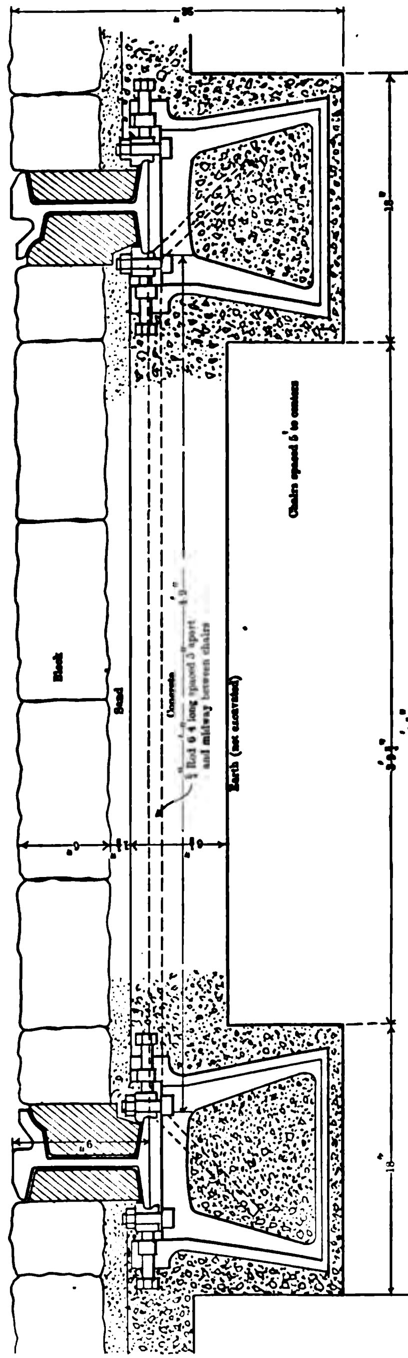


FIG. 25.—Track Construction Used in Philadelphia.

at the base, 16 inches on top and 15½ inches high, leaving 2½ inches between the top of the concrete girder and top of rail. This space was filled with asphalt, the entire roadway of the street being paved with this material. It is thus seen that the rails were nearly buried in the concrete beam. Ties 6 inches x 8 inches x 8 feet were placed every 12 feet, and tie rods every 6 feet. The forms were held together at the top by U-shaped iron bands. The cost of this double track construction exclusive of rails and ties was $3 per lineal foot. In general it has been found not advisable to permit an asphalt pavement to come in contact with the rail, but concrete forms such a large proportion of this construction that no bad results are anticipated.

Fig. 25 shows a form of construction used in Philadelphia which is one of the best. As will be seen from the illustration each rail rests upon a beam of concrete 18 inches wide at the base and has a depth of 22 inches below the surface of the paving. The two beams are joined by a bed of concrete 6½ inches deep extending across the track. This mass of concrete is continuous along the track, and at intervals has imbedded in it reinforcing rods crossing the track from rail to rail with their ends bent down into the side trenches to gain a firm anchorage. One of the principal features is the use of special iron yokes placed at intervals in the concrete beneath the rails. These are provided at the upper ends with guide lugs, in which are adjusting screws. These screws bear against holding blocks that grip the base of the rail, thus making it possible to adjust the rail to exact gauge by means of the screws.

In laying the rails the trench is first excavated and surfaced. Temporary cross ties are then placed at intervals, the rails laid on them and roughly brought to gauge. The rail is clamped to the ends of these temporary ties by means of clips and nuts, because it was found advisable to cover the tops of the ties by a channel iron. After the rails are thus secured the side trenches for the concrete beams are dug, and when the yokes are hung in place on the rail, the work is ready for the concrete. Fig. 26 shows it in this condition.

In attaching the yokes, shims are placed between the base of the rail and the top of the yoke. These shims as well as the temporary ties are removed after the concrete is in place. The

object of the shims is to prevent the yokes from becoming the sole points of support for the rail because of the fact that con-

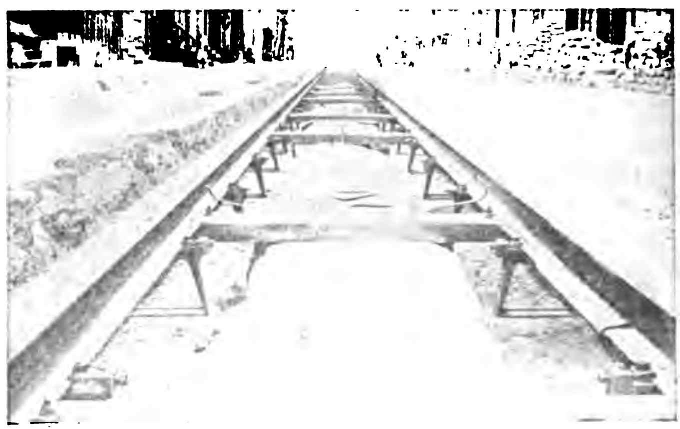


Fig. 26.—Philadelphia Track Construction Ready for Concrete.

crete shrinks in setting and would draw away from the rail. But the removal of the shims allows the concrete to be a continuous support, while the anchor bolts in the yokes hold the

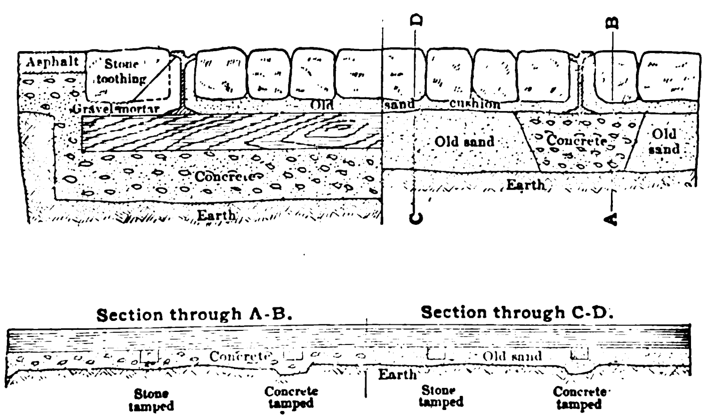


Fig. 27.—Method of Paving between Rails in Buffalo.

rail down and anchor it firmly. This construction is admirably suited to prevent the heaving of the rail in waves, as is sometimes the case, due to vertical expansion.

In Buffalo, N. Y., two forms of track construction are employed both of which depend mainly on concrete to support the

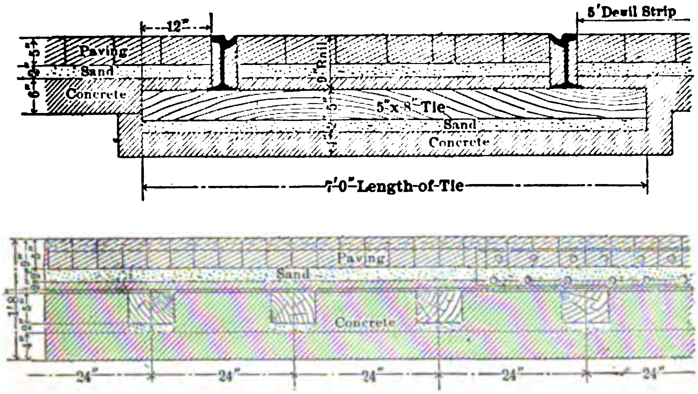


Fig. 28.—Track Construction Used in Cleveland, Ohio.

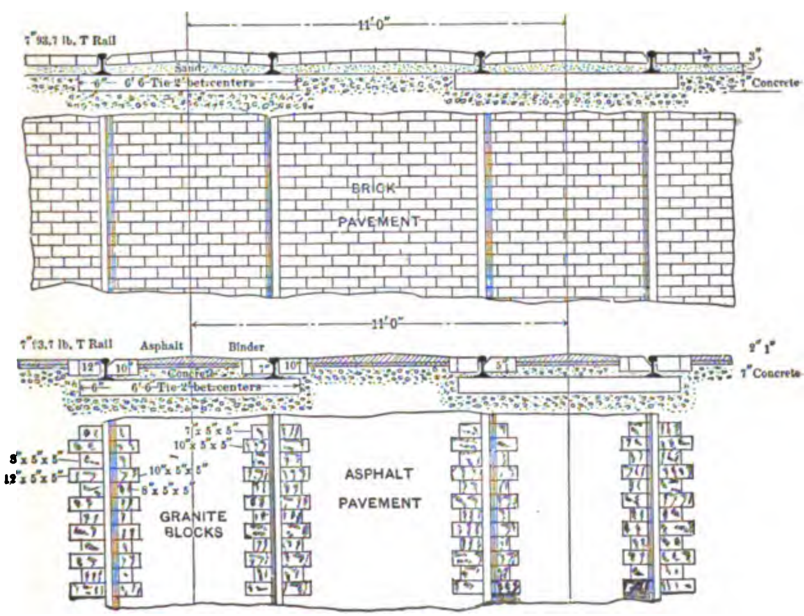
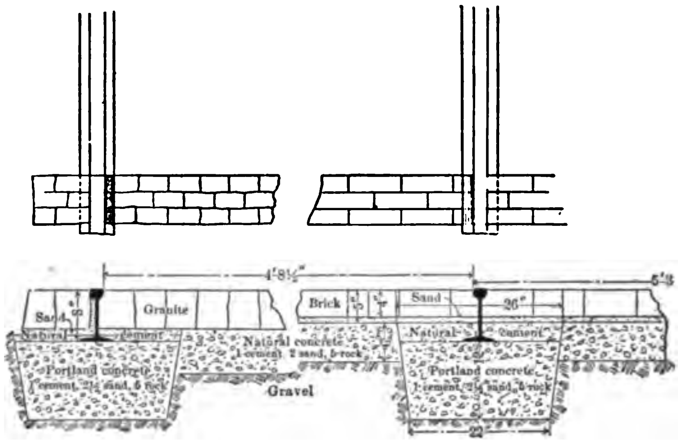


Fig. 29.—Track Construction in Asphalt Pavement in Milwaukee.

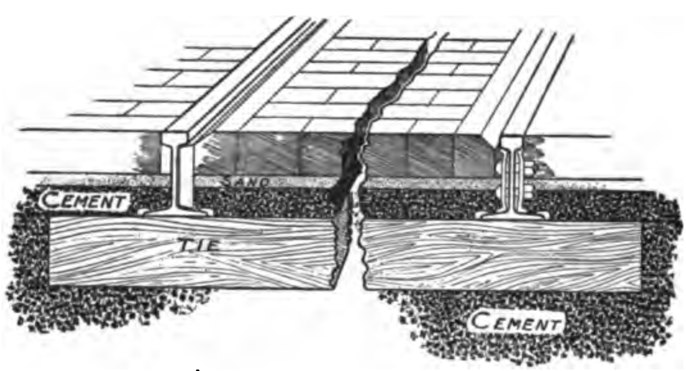
rails. Where granite block paving is permitted the full width of double track, including devil strip, the track is supported on a solid bed of concrete extending about eight inches below

the base of the rail. The track is held to gauge and partially supported by ties placed every 5 feet. Every other tie is metal, the others being of wood.

In places where asphalt paving is laid in the devil strip the concrete beam form of construction is employed. A wedge-



In Granite and Brick, St. Paul and Minneapolis.



FIGS. 30 and 31.—Track Construction Used in Battle Creek.

shaped beam of concrete 18 inches wide at the top, and 8 inches deep, is laid under each rail. Ties are placed every 5 feet. Concrete is tamped under every other tie at the time the concrete stringers are laid. The remaining ties support the track during construction when the concrete is being laid, and are tamped with broken stone. The paving between the rails in

this case is supported simply on sand foundation except where it is above the ties. Fig. 27 shows both forms.

Fig. 28 shows a form of construction in use in Cleveland, Ohio, which explains itself.

Fig. 29 gives plans and sections of the standard track construction in asphalt and in brick pavement in Milwaukee, Wis. Track is laid on wood ties, with 6 inches of concrete tamped under each, and the paving foundation is also 6 inches of concrete as shown. In asphalt streets granite toothing blocks are laid along each rail.

Figs. 30 and 31 shows track construction employed by the Twin City Rapid Transit Co., and also that used in Battle Creek, Mich.

Cast-welded Joints

The results of the experiments show that the cast-welded joint is a success, and the joint is now applied to many miles of rails in pavement in the United States. Engineers now thoroughly understand, as they did not five years ago, what is necessary in order that the weld made at the joints of the rail will form a molecular integral connection between the casting and the rail itself. It has been found that the perfection of this weld does not so much depend on the composition of the cast metal, which is usually pig-iron, as it does on bringing the rail surface to such a temperature that it will amalgamate with the cast-iron surrounding it.

This temperature is attained in several ways. The usual method is to employ a sufficient mass of metal around the joint so that the actual thermal units are sufficient to raise the temperature of the rail to the required point. Where a sand mold is used around the joint the sand chills the outside iron, and rapidly reduces the total heat in the cast joint, so the weight of the metal around the joint has to be increased until sufficient molten metal has been poured into the joint to effect the amalgamation required.

An expedient to reduce the mass of metal required, devised by Mr. Hoffman, is to put an iron sheath instead of a sand mold around the joint. This sheath is supported by the rail against the joint, and the space between the sheath and the joint is poured full of metal. This reduces the conduction of

heat from the mass of molten metal, and allows an integral weld to be made with less weight of metal per joint.

Another method, devised by Mr. Annable of the Grand Rapids Railway Co., is to allow the metal to overflow the mold on the opposite side from the pouring side. In this way the temperature of the joint can be brought up to the required degree with a small mass of metal. The overflow is afterwards broken off and remelted again for other joints. This weld is made an inch or so below the head of the rail, a method which has the advantage of not bringing the head of the rail in such close contact with the molten metal and thus run the risk of annealing it.

It has often been assumed that all rails could be cast-welded, and this erroneous impression has caused a number of failures. Some rails have a composition which will anneal at the temperature attained with the welded joint, and others will not. It seems to be a fact that those rails which are high in manganese and low in phosphorus are self-hardening, that is, they will harden again on cooling, but that a low-carbon rail will anneal under the heat of cast-welding. This will cause a soft joint, which will soon be pounded to a flat joint (or the metal will flow) by the passing over it of the wheels. For this reason, before deciding to lay cast-welded joints, it is desirable first to test the rail for its self-hardening qualities, to determine whether it is of proper composition.

The cast-weld has been generally admitted, since 1898, to form an electrical connection between the rail ends, which, as a rule, is lower in resistance than an equal length of rail, provided the weight of the metal around the joint is two and one-quarter times that of the weight of rail per yard. But it is found by test that the resistance will increase toward the end of a pour, if the temperature of the metal is not maintained. Cast-welding the rail-joints of a track will not insure the permanency of its alignment, unless the rails are held in the pavement and concrete, so that no longitudinal motion of the rails can take place. In laying road-bed designed for cast-welding, therefore, it is essential that the grouting and concrete against the rail be properly applied, and well tamped immediately under the foot, and around the web of the rail. It has also been found that in mixing this concrete a cement, high in lime,

will produce a greater cohesion between concrete and rail than ordinary cement will give. Experience has also shown that the best results in cast-welding have been obtained when the pavement has been laid complete, except at the joints, before welding, and then completed after welding. If the joints are cast on open track and the paving then laid, the difference in temperature between morning, noon and night is sufficient to warp the track, so that it is difficult, if not impossible, then to align it without cutting the rails.

Welding up special work, and welding the main track with the special work, are directions along which developments should be made in order that the electrical and mechanical continuity of the rail shall be insured.

Breakage is largely a question of sub-ballast and pavement condition. It is largest in asphalt pavement and lowest with granite paving or toothing block set in concrete. In about 40 miles of the former class of paving 4.8 per cent. breakages after four years' service have been found. The reason for breakages in asphalt is that the dark surface of the asphalt absorbs heat readily, which, in turn, is transmitted to the rail. The stress to which the rail is subjected on this type of pavement is also much larger than with the less absorbent granite block or brick. Wood block pavement is hardly a pavement in which a cast-weld can be successfully applied, as there is no foundation to which to secure the rail to prevent longitudinal expansion, due to temperature changes.

The number of broken cast-welded rail-joints averages about two per cent. of the total, at the end of three years. The joints at which the welds are found most liable to break are at the ends of tangents and at top of the grades.

For the purpose of prolonging the life of a light rail in a poorly paved street, cast-welding is certainly an electrical improvement, but to weld the joints for the purpose of improving the wearing qualities of the track is of doubtful mechanical and commercial value.

The following tables show the cost of electric welding under the method employed by the Lorain Steel Co. while they were carrying on the work for the Public Service Corporation of New Jersey in Camden, N. J.

Table XVII shows a summary of the cost of electrically weld-

ing these joints, including contract price of $5.25 per joint. Table XVIII shows the cost per joint, type of paving, type of rail section and number of joints welded on each of the five streets on which the work was done. As will be seen from these tables, the cost per joint varies from $6.632 to $10.438, with an average of $7.635. This price, however, should be considered in connection with the maintenance charge of the joint with which this price is compared. It is estimated that the life of the welded rail on the Haddonfield Pike will be eight years, whereas during the last two years with angle plate joints this track has cost the company about $1 per joint each year for tightening bolts and shimming. This maintenance work has only temporarily relieved the situation, for each year the joint has been worse, and it was estimated that at the end of four years the rail would have been so bad at the joints that the track would have to be relaid. In other words, it is expected that in this particular case, by electrical welding, the life of the rail will be practically doubled at a less cost than would have been required simply for maintaining angle plate joints during the life of the rail.

Table XVII

COST OF ELECTRICALLY WELDING 3,087 JOINTS IN CAMDEN, N. J.

Cost of labor	$7,081.24			
Cost of material	581.09			
		$7,612 83		
Credit from sale of old fish-plates and bonds		2,816.59		
			$ 4,795.74	
Cost of welding 3,087 joints, at $5.25 each			16,206.75	
Cost of replacing asphalt, 899.6 yds., at $2.53; 117 yds. at $2.51			2,569.65	
Total cost of operation				$23,572.14
First cost per joint, labor				2.277
First cost per joint, material				.188
First cost per joint, labor and material				2.465
Cost per joint, labor and material, after credit is deducted				1.553
Final cost per joint, all labor, material, welding and asphalt charges				7.635
Cost per mile under similar conditions, 30-ft. lengths				2,687.52
Cost per mile under similar conditions, 60-ft. lengths				1,843.76

TABLE XVIII

COST, PAVING AND RAIL SECTIONS ON THE DIFFERENT STREETS

Haddonfield Pike, 7-in. girder (P. S. Co. section No. 238 and Cambria No. 824); rubble stone on sand, 989 joints	$6.684
Moorestown Pike, 9-in. girder and 7-in. girder (P. S. Co. sections 238 and 200); rubble stone on sand, 1,128 joints	6.704
Broadway, 7-in. girder (P. S. Co. section No. 238), asphalt between rails and part of shoulder, Belgium block along rail, on 6-in. concrete, 715 joints; Kaighn Avenue, 7-in. girder (P. S. Co. section No 238), bricks between rails and shoulder, on 6-in. concrete, 64 joints; total, Broadway and Kaighn Avenue, 779 joints	10.438
State Street and River Road, 7-in. girder (Cambria section No. 884); rubble stone on sand, 191 joints	6.632
Average cost per joint, 3,087 joints	7.635

Below are given data concerning the cost of cast-welded joints. The operating wages, repairs and supplies contain a small percentage of increase over actual costs to cover general depreciation. The 2,414 joints were applied to rails ranging from 5 inches to 7 inches in height. In addition to these figures about $1.00 per joint must be added for the cost of opening and closing the street, i. e., the removal and replacement of the pavement at the joints.

TABLE XIX

DATA ON 2,414 CAST-WELDED JOINTS

		Per Joint.
Operating wages	$1,590.78	$ .659
Repairs	704.83	.292
Power and lighting expenses	40.10	.016
Supplies	3041.30	1.260
Injuries and damages, 5 per cent	362.10	.150
Interest, taxes, insurance	288.00	.119
Miscellaneous	653.35	.271
	$6,680.46	$2.767

The Lorain Steel Co., who contract to make electrically welded joints, ask from $5.50 to $6.00 per joint including all expenses. The number of joints determines which shall be the contract price.

Thermit-welded joints, made on a rail of average size, will cost about $4.50, of which the chief share is the price of the thermit welding material. To this should be added $1.00 to $1.25 for opening and closing the street.

Rail Bonds

A question always asked is, what is the best bond? The answer is, the best workman makes the best bond. The care exercised in applying them may make them effective connections or so much junk. Certain points are essential; with the best care bonds should not be put in in damp or wet weather, as any moisture will start corrosion.

The mechanical joints as electrical connections stand in the following order: the electrical weld gives the most uniform resistance, running about the same as the rail, depending upon the size of the splice bar used; the cast weld varies as the temperature of the metal which determines the degree of amalgamation, the joints in succession gradually increase in resistance as the temperature of the metal falls. In one heat, with more than one pouring in, a joint increases its resistance. Thermit joints tested appear very well, although enough have not yet been tested to determine their exact location in the scale, but they are not superior to the electric weld. In regard to the mechanically placed bond, it can only be said generally that when these bonds are installed by the line department, they give better results than when installed by the track department, and when one man has charge of and is responsible for all bonding, its installation and testing, markedly better results are attained than where it is done in a haphazard fashion by the track gang.

CHAPTER IV

LOCATION OF THE POWER STATION

In the location of the power station a number of facts have to be considered in order to determine, from both the engineering and operating standpoint, what will be the best situation available. The general solution is to have the power station in the center of distribution of the territory over which it supplies power. The geographical center need not necessarily be the electrical center, for grades at one end of the system, or a more frequent schedule here or there will both tend to move the station away from the geographical center and nearer the distribution center of the system. Where substations are used to extend the area of distribution for a power station, and the latter serves only a small portion of the system by direct current, the copper values are not such an important element, and the station can be located in reference to facilities for obtaining water, coal and other conveniences.

The necessary conditions existing at the point selected, in addition to an abundant and suitable water supply, and the delivery of coal at a low cost without rehandling, are that proper foundations can be secured without unusual difficulty or high cost; that land shall not be too high in value and the location not so far removed that the cost of distribution would be excessive. Often in the past a power station has been located at a certain point because of the low cost of land, and this was the determining factor, whereas the other investments, which vary with the location, may cause greater expenditures than the difference in the cost of land at the place proposed, and the cost at a more suitable location. The profit arising from a proper location would be found in the reduced operating and transmission expenses.

In order to clearly understand the commercial value of these variables from which the best average power station location can be determined, the earning value in dollars for each avail-

able location should be determined separately. The land on which the station is to be located should have sufficient stability to sustain the foundations and structures, and an examination should be made by means of borings to determine the character of the subsoil, in order that capital will not be wasted in attempting to erect a structure on ground that is unable to carry it without excessive foundation cost. The value of the soils in relation to the pressure in tons per square foot which they will safely bear is as follows:

Character of Soil.	Bearing pressure, in tons, per square foot.		
Hard rock	25	to	36
Rock, soft	5	to	10
Clay on thick beds, dry	4	to	6
Clay on thick beds, medium dry	2	to	4
Clay, soft	1	to	2
Gravel, coarse and well cemented	8	to	10
Sand, compact	4	to	6
Sand, clean and dry	2	to	4
Soils in quicksands	.5	to	1

These values may vary in different parts of the ground on which the foundation rests, and where the machinery and walls will require a soil resistance of over two tons per square foot, care should be exercised in determining their actual bearing values and reliance not be placed on an empirical value. Often the cost of the foundations is greatly increased owing to the difficulty in obtaining uniform stability of building walls and internal foundations due to the inequality of the bearing-surface of the soils underlying the proposed station. The commercial value of the site may be greatly reduced due to these physical conditions of the subsoil.

Filled-in ground, wet, fine sand and quicksand, should also be considered in view of the vibratory character of the load they will have to sustain. When the ground conditions are not suitable for station foundations they should be adopted only in case of necessity, for foundation costs have in some cases exceeded the cost of the whole of the remainder of the station structure, whereas normally they do not exceed 16 per cent. of the cost. In such cases the land cost could be doubled at a profit if normal foundation conditions were offered. In two cases an undiscovered soft spot on the foundation line

cost the company a large portion of their capitalization to overcome the difficulty, and seriously jeopardized the future of the undertaking. These points are brought up in order to emphasize the necessity of care in the preliminary steps toward locating a station, and nothing should be taken for granted by the careful engineer. The foundation cost is not reflected in the future operation of the property unless it is faulty, and a maintenance charge has to be made.

The water supply is a question which has a direct influence on the selection of the type of boilers and engines which will be used, and on the economy that can be anticipated from operation. The water demand varies with the kilowatt output of the station. Table XX is given showing the water required at ordinary efficient temperature. Column one gives the least possible quantity of water that would be sufficient by using the water over again, with surface-condensers, skimmed, and fed back into the boiler. Column two gives the least water required when using free exhaust. Column three gives the least water supply for boiler-feed and air-cooled condenser. Column four gives the least water required for boiler-feed and water-cooled condensers where condensing water is discharged.

TABLE XX

Daily Station output in kw.-hr. based on 20 hours operation.	Water required in cu. ft. per 20 hrs. when condensed, skimmed and used overagain.	Least water for boiler-feed in cu. ft. per 20 hrs. when using free exhaust.	Water required in cu. ft. per 20 hrs. for boiler-feed and air-cooled condensers.	Least water in cu. ft. per 20 hrs. required for boiler-feed and condensers.
1,000	31	630	94	22,050
1,500	46	920	138	27,300
2,000	59	1,180	177	35,600
4,000	115	2,300	345	69,000
5,000	140	2,800	420	84,000
7,000	198	3,960	594	118,500
10,000	247	4,950	742	148,000
25,000	504	10,090	1,513	301,000
50,000	860	19,200	2,780	578,000
75,000	1,450	29,000	4,350	875,000
100,000	1,755	35 100	5,265	1,050,000
200,000	3,600	72,000	10,800	2,160,000
300,000	4,800	96,000	14,400	2,860,000
400,000	6,200	124,000	18,600	3,710,000
500,000	7,600	152,000	22,800	4,570,000

These figures include the water required for the auxiliaries as well as evaporation and loss in air-cooling. Where a natural source of water is to be drawn from it should show

this volume, at the low summer or fall flow, passing in twenty-four hours, or storage would be necessary to give sufficient water. Table XXI gives the size of the pipe which will discharge varying volumes of water in twenty-four hours at a velocity of one hundred feet per second.

TABLE XXI

Diameter of Pipe in inches.	Cubic feet in 24 hours.
1	770
2	2,600
4	12,700
6	29,100
8	49,600
10	79,500
12	112,040
15	134,000
20	234,200
25	1,065,000
30	5,251,000

Where a considerable storage has to be provided in order to use the 24-hour flow for the 20-hour consumption, or to make up for a deficient average mean flow, evaporation for this storage must be allowed for, depending upon the altitude and latitude of the reservoir.

The character of the water available should be examined as to its value for steaming purposes in respect to any effect it would have on the boiler. Waters high in lime and carbonates require more coal to evaporate them than other waters. Mountain streams high in organic matter give boiler troubles such as foaming, and the concentration of this matter in the boiler produces a chemical action on the metal surfaces themselves leading to pitting or the formation of scale. Water charged with sulphur also deteriorates the boilers, and piping through which they are conducted. The condition of the water proposed to be used should be thoroughly determined before it is accepted and before the location of the station is definitely settled.

The cost of coal delivery is another important item that bears directly on the power station location, and this depends on rail or water transportation facilities. The storage room required varies, and may be decreased as the facilities for obtaining coal increase. The question of the local handling of the coal, whether it can be done directly from a siding into

a chute with conveyors, or whether the station can be located adjacent to navigable waters so that barges can be unloaded directly into the storage bins is most important. Interurban roads are making a practice of hauling coal over their own tracks where the station cannot be located along a steam freight line, and use their motor cars or locomotives for this haulage, but in some states the steam roads will not allow their freight cars to be waybilled or handled over electric tracks. Whether this condition exists or not should be determined for each locality. The 10,000 kilowatt-hour station will require 11,300 tons per year of 2,000 pounds, or 376 freight cars of 30 tons each. This coal could not be delivered for less than $\frac{6}{10}$ of a cent per ton mile including power, labor and depreciation, or $67.80 per annum to haul it one mile, or 5 per cent. on $1,356.

When coal has to be rehandled the price for transporting it to the station increases rapidly, and where it has to be loaded into cars the price rises to 22 cents per ton mile, delivered. This would increase the price of coal delivery to the above station to $2,480, or the equivalent investment value at 5 per cent. of $49,600.00.

In regard to the location of the power station relative to the railroad to be operated, the theoretical location or the point of maximum economy in copper conductors is that point on the system that will be the electrical center of gravity of those loads which conform to the maximum schedule. Let us suppose the current to be ponderable and have a unit weight, the center of gravity of the system would be the economical center for the point of distribution. Grades, curves, heavier traffic on one end of the road, smaller bonding and rails in one part of the system than another, are all factors which determine the location of the economical center. The electrical center will be distorted from the geometrical center of the system if any one of these values rises above the average value. Long city stretches, with reduced speed and increased number of stops per mile, increase the energy demand required, and consequently tend to draw the economical point of distribution towards this condition. As to speed and stops, they both increase the average and maximum demand.

To illustrate how the shifting of the station from this point of maximum economy will affect the cost of conductors we will

consider as an example a 19-mile road, operating four equipments at a schedule speed of 19 miles per hour. Without going into the detail of the feeder computation here, suppose that two 3/0 trolley wires were used the whole length of the road, and they were so fed with copper that the mean drop would be 15 per cent.; assume also that the road is level and the load symmetrical; then the geometrical center of the road would be coincident with the point of least copper investment. The total investment for copper in this distributing system would be $25,460. By moving the station one mile away from the center of distribution, copper cost $27,400; two miles away copper cost $41,800; three miles away, copper cost $68,900. At this point we have practically reached the economical limit for direct current feed under conditions selected. After feeding 11.5 miles from the power station with direct feed a booster or substation would have to be resorted to, affecting the whole investment. The copper could be reduced $26,000 and the booster would cost $7,900, making a total investment for the next mile moved away from the center of distribution $33,900, an apparent capital saving, but the losses inherent in the use of a booster in the above case would amount to about $3,800 per annum, or the interest on $76,000 capital. This would make the total cost of the conductor system where the station is located 7.5 miles from one end of the road and 11.5 miles from the other end, $109,900, including the copper cost and the annual cost of the booster losses.

In practice the determining of the most economical location can only be made by ascertaining the point at which the sum of all the investment and operating losses is least. Foundation and water are the two elements necessary to be present on the property or obtainable, the others can be secured by construction.

In small plants it has been a good practice to locate the car house and repair shop near the power station on account of reduced heating cost and the interchange of labor. Car house lighting can be done by a small auxiliary unit and in a number of ways economies can be effected and expenses reduced by the adjacent location of the car house and station. If these are located in the center of traffic, it means the least number of idle car miles the cars have to be run in order to establish

and complete their schedules at the beginning and ending of each day.

The location of the power house in cities involves the same conditions as does the interurban location except that instead of dealing with an approximately straight line system of transportation, the system will be distributed over an area. The solution is the same, for by considering each line independently, and then combining the different centers of gravity found it is reduced to the final center, which will be the ideal location from a distributing point of view. But the cost of distorting the distributing system, due to other conditions which necessarily arise in power station location in densely populated districts must be determined by the value of the different properties available compared with all the variables entering into their selection.

CHAPTER V

OVERHEAD CIRCUIT

Overhead Construction

From the time when the first successful underrunning trolley wire came into use there have been few changes in the methods of construction until recently. Hundreds of miles of trolley lines in cities and in the open country are still in operation, and others building, with almost the same character of construction as that in use from 10 to 15 years ago. The principal reason for this is undoubtedly that such construction was fairly satisfactory in the results obtained and that other problems of railroading had to be solved first.

The cross suspension of the trolley wire has been practically unchanged, but when bracket arms came into use the first change was to the flexible bracket suspension, for when the supporting hanger was attached directly to the arm it was too rigid and caused serious arcing when the trolley wheel passed under it.

Figure 8 trolley wire was tried to a considerable extent where traffic was heavy. It permitted the employment of mechanical ears and gave a smooth under surface. One of its principal disadvantages was the tendency to turn over or twist between supports. It was succeeded by the grooved wire, which has all the advantages of the other and none of its faults. Numerous improvements have been made from time to time in line material, but these have been in the way of better insulation and greater strength, rather than in any radical change in design. It is not the intention to enter into the subject of high tension transmission lines for the construction of these differs frequently from that employed by the average railway.

In some of the large cities, especially at the intersection of two or more streets, overhead construction is oftentimes complicated and difficult. Here it is seen at its best, or worst, as the case may be. In a number of cities it is a curious fact that

at certain important intersections the overhead work is so bad as to be unworthy of the name. At other points, sometimes in the same city, the work is so well designed and built that the railway company alludes to it with pride. Figs. 32 and 33 are examples of good designing. Of course much depends on the ability to place the poles in advantageous positions.

Table XXII gives details of construction in the cities

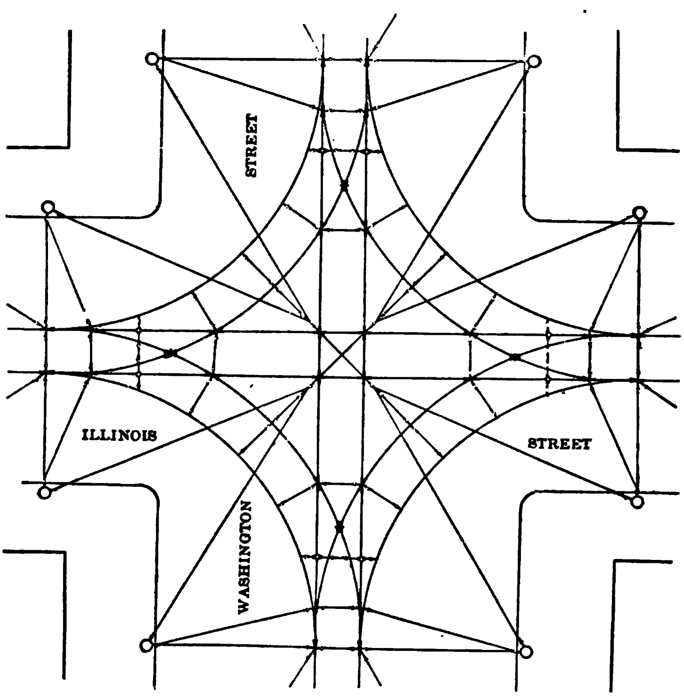


FIG. 32.—Overhead Construction at Street Crossing.

named. Iron poles are used in most cases, and feeders are underground in many. No. 2/0 trolley wire is generally used though there is a tendency always toward No. 3/0 or 4/0 as traffic increases.

Center pole construction in wide avenues or boulevards is frequently used and presents a fine appearance, especially where ornamental brackets are used. Side bracket construction in cities is used on the sides of streets in residential dis-

tricts. Fig. 34 illustrates the type of bracket in use in Cleveland, Ohio.

Figs. 35 and 36 show the usual style employed on interurban roads, though a low tension feeder is frequently carried on

TABLE XXII

OVERHEAD CONSTRUCTION

Name of City.	Kind of Trolley Wire.	Size of Span Wire.	Kind and Maximum Size of Feeders (Overhead).	Lightest Poles for Straight Line Work.	Number of Insulators between Trolley and Pole.	Type of Underground Conduit	Volts Drop for which New Lines are Calculated.
Baltimore U't'd Ry. & Elec. Co.	Round 0 & 00	5/16 in.	500,000 cm copper	5-4 in.	2	Terra cotta	50
Boston Elevated Ry.	Round 00	5/16 in.	1,000,000 cm copper	750 lb. 6½-5½-4½ in.	2	Single duct terra cotta	100
Buffalo Ry.....	Round 00	3/8 in.	500,000 cm copper	....	2	....	100
ChicagoCityRy.	Round 00	3/8 in.	500,000 cm copper	900 lb. 7-6-5 in	3	Mult. duct terra cotta	75
Cleveland Electric Ry.........	Round 00	5/16 in.	1,000,000 cm copper	625 lb. 7-6-5 in.	......	....	125
Denver City Tramway Co...	Round 0	5/16 in.	500,000 cm copper	. ...	2	....	[illegible]0
Detroit United Ry..........	Round 00	5/16 in.	1,000,000 cm copper	675 lbs.	2	....	100
Indianapolis Traction & Terminal Co.......	Round 00	3/8 in.	500,000 cm copper	600 lbs.	2	....	......
Milwaukee Electric Ry. & Light Co.......	Fig. 8 = 000	½ in.	....	850 lbs. 8-7 in.	2	Single duct tile	......
Minneapolis Twin City R. T. Co.	Fig. 8 = 00	3-11	500,000 cm copper	....	2	Multiple duct tile	25
Philadelphia Rapid Transit Co.	Round 00	....	....	915 lbs.8-7-5 in.	2	....	50
Pittsburg Rys. Co.	Round 00	5/16 in.	1,500,000 cm aluminum	....	.. ..	Cement lined and single and multiple duct tile	50
San Francisco United Railroads	All kinds in use	5/16 in.	1,000,000 cm copper	7-6-5 in.	2	....	100
St. Louis Transit Co.	Round 00	5/16 in.	1,000.000 cm	545 lbs. 6-5 in.	2	Cement lined iron pipe	100

the pin-marked telephone in the illustration. The bracket arm is 1½-inch or 2-inch iron pipe and the top brace a ½-inch iron rod.

Some roads prefer a bracket with a lower brace added as shown in Fig. 37, but this form is probably not used as much as it formerly was, on account of the under brace being considered unnecessary.

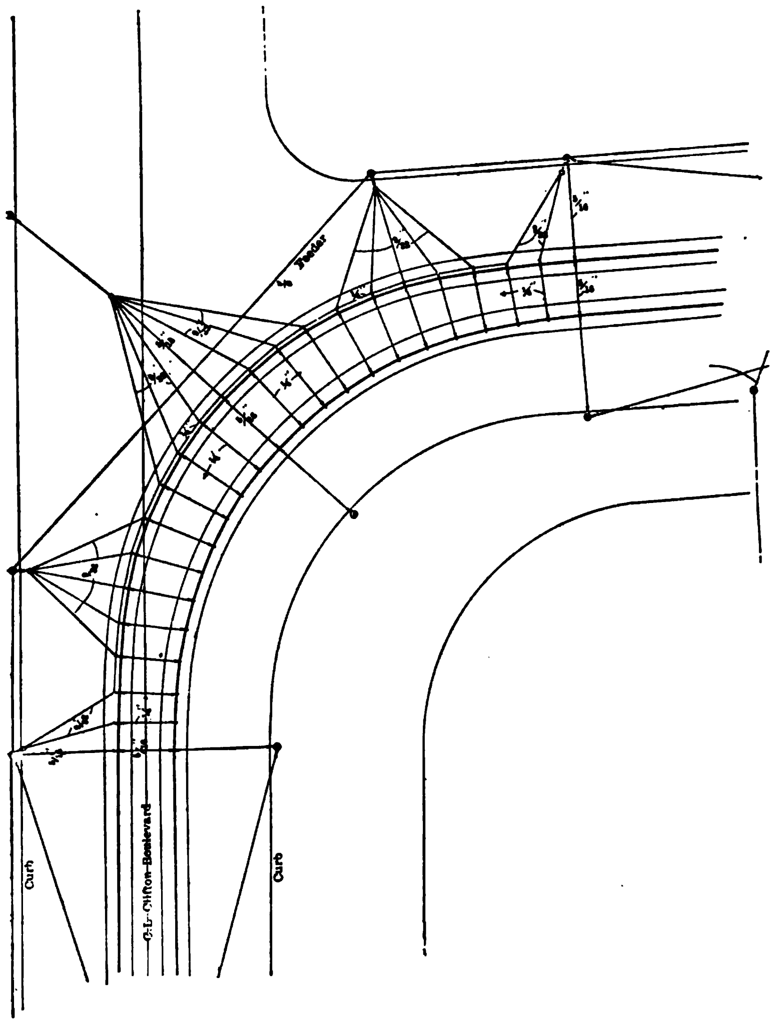


FIG. 33.—Overhead Construction at Corner.

Fig. 38 illustrates the standard construction of the Chicago and Milwaukee Railway on their interurban lines and is a fair example of standard construction for double track span work in the country.

A not uncommon practice on single track interurban lines is the placing of two trolley wires on the same suspension about 6 inches apart. Cars all use the right-hand wire looking

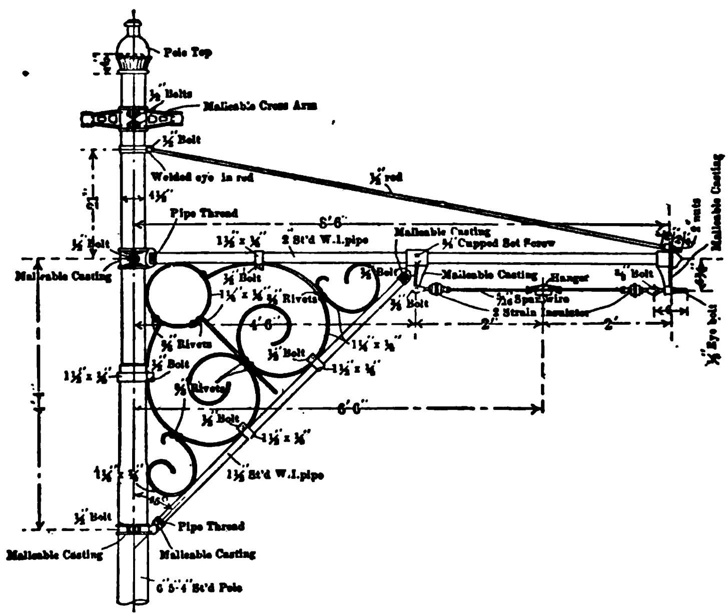
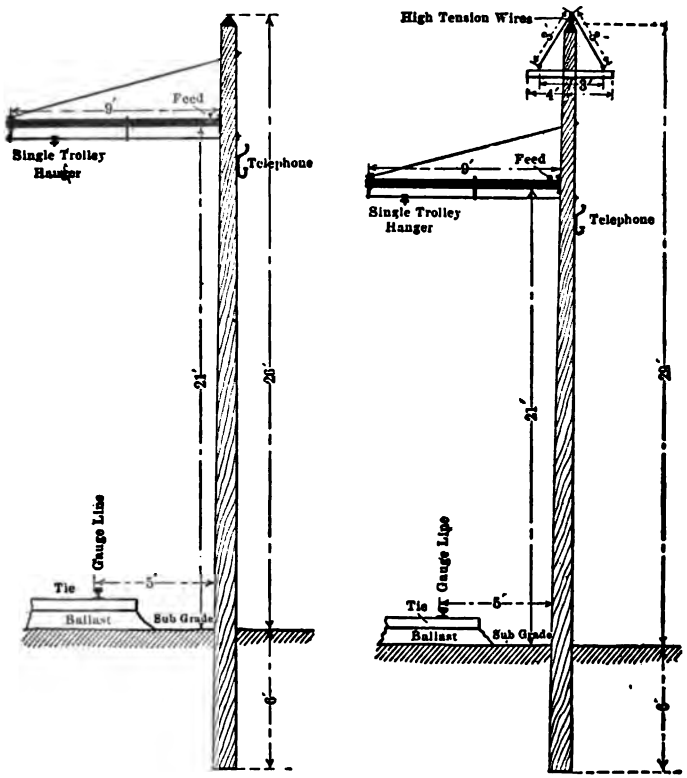


FIG. 34.—Type of Bracket Used at Cleveland, Ohio.

ahead, so that those running in opposite directions use different wires. This eliminates all overhead frogs, as one wire leads over the turnouts while the other remains in the main line. The extra copper can be deducted from the feeders so that it is but a small extra expense, besides the line is not so easily tied up if one trolley wire breaks. Fig. 39 gives details of such a construction.

A grade crossing with a steam road is objectionable and dangerous, but circumstances render many of them necessary. The trolley wire must be raised to a height of 22 feet or 23

feet, which reduces the pressure of the trolley wheel on the wire, rendering it more liable to leave the wire at a critical time. To guard against this there is in use in some states an arrangement similar to that shown in Fig. 40. It consists of an inverted semicircular metallic trough, usually sheet iron, through which the trolley passes in electrical contact with the



FIGS. 35 and 36 —Types of Bracket Used on Interurban Roads.

top of the trough. The trough is thus kept alive and the wheel rolls within it on its flanges. This adds greatly to the safe passage of such crossings.

The question of lightning arresters on interurban lines is generally of considerable importance. It is not so much which arrester to use, for there are several good types, but

how many, and how to properly install them. As an example of experience a certain interurban road was built entirely on private right of way. Rails on the ties were above the ballast and but few chances existed for good contact between rails and ground. One arrester per mile was installed and the ground wire bonded to the rails. The first severe lightning destroyed most of the arresters. The agent for the arrester said there were too few, they ought to be 1,000 feet apart,

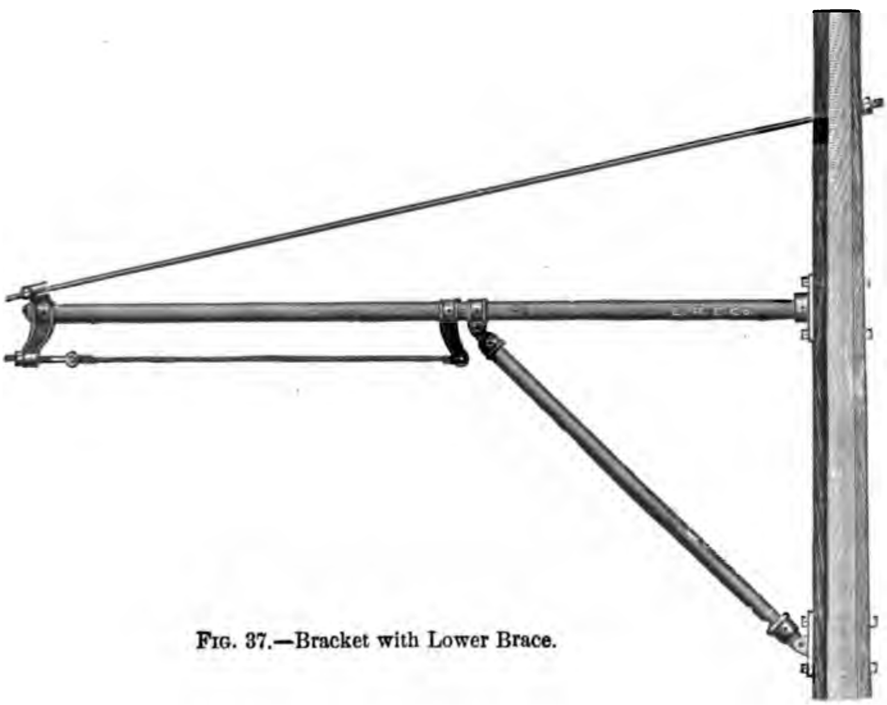


FIG. 37.—Bracket with Lower Brace.

which advice was correct provided the company desired to invest in so many, and also provided they were properly grounded.

It was decided to ground them as follows: The tap was taken off the rail and the No. 6 ground wire was wrapped around the end of a $\frac{1}{2}$-inch galvanized iron pipe about 10 feet long and soldered. A hole about 3 feet deep and 1 foot diameter was dug and the pipe driven down through the bottom until its top was about flush with the surface of the ground. The hole was

then filled in with charcoal and thoroughly wet down. Advantage was always taken of small streams and damp places in locating the grounds, which were as close as convenient to the pole carrying the arrester. Little trouble was experienced thereafter.

Arrester grounds are usually specified as consisting of from 2 to 4 square feet of sheet copper to which the ground wire is soldered and buried in charcoal or coke, which should be damp.

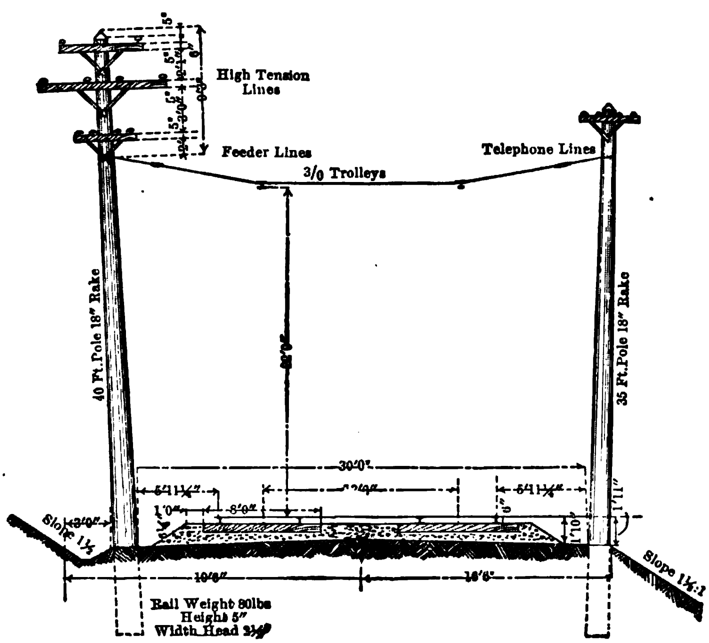


FIG. 38.—Standard Construction of Chicago and Milwaukee Railway.

This method is possibly better than the above, but all are not willing to go to such expense and trouble necessary for the line arresters.

One most important change in the character of overhead construction is the importation of the catenary suspension. It is a natural result of the demand for high speed and the necessity for high tension in the working conductor. With the old construction heavy strains were necessary in order to get the trolley wire taut enough for the trolley wheel to have a reason-

able chance to stay on, with consequent risk of breakage everywhere and of jarring hangers loose, or of jumping the wire near the hangers and knocking them off by a blow of the

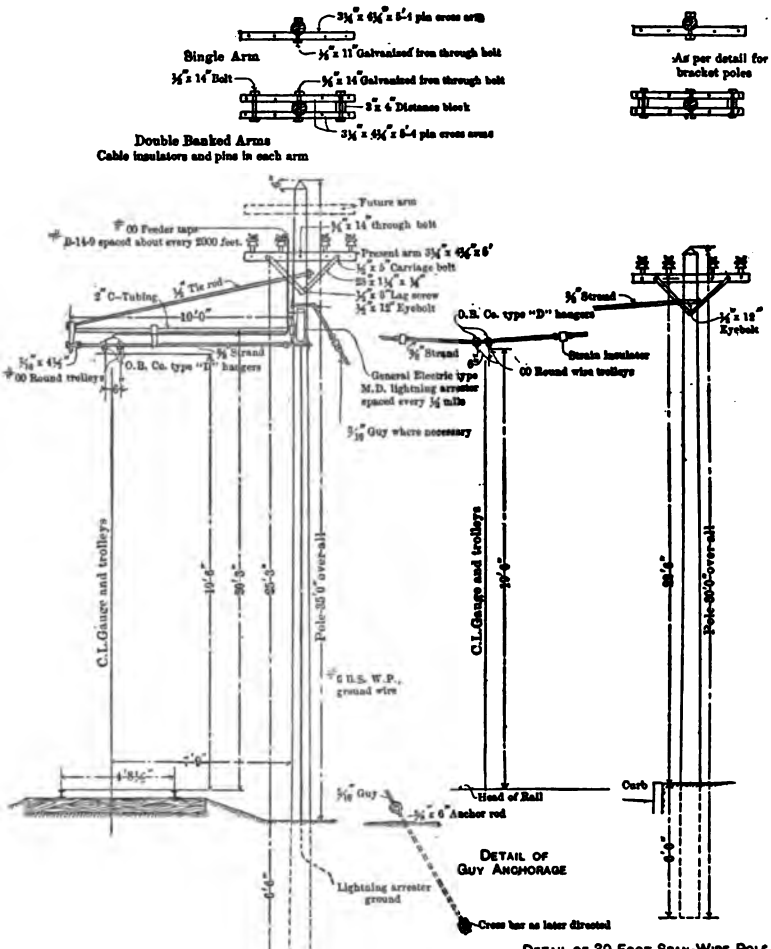


Fig. 39.—Details of Double Trolley Construction for Interurban Line.

trolley pole. The catenary construction relieves these difficulties and at the same time gives an exceedingly even and smooth running line, equivalent to a continuous flexible suspension. For high voltage lines designed for high-speed inter-

urban service this is of very great importance, and it has provided a solution of the problem the necessity for which was rapidly becoming imperative. So great are its advantages over the old form of construction that the added expense should not prohibit its use in the ordinary low tension d. c. interurban roads. In a light construction of this kind the immediate result is to make it possible to decrease the number of supports or bracket poles while gaining at the same time a better alignment of the trolley wire.

At the present time the catenary overhead construction has been placed in use on a suburban extension of the New Orleans

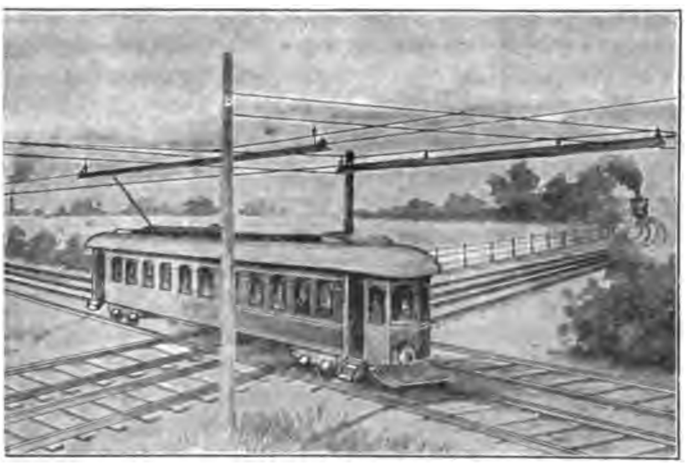


Fig. 40.—Safety Trolley Guard at Steam Road Crossing.

Railways Co., in an ordinary 550-volt continuous current line, and results indicate entire satisfaction. The poles were spaced 100 feet apart, though it is believed that 150 feet or slightly more would be entirely safe.

The messenger wire, from which is suspended the trolley, is ½-inch galvanized steel stranded wire and is supported by 10-foot steel tube brackets attached to the poles by the usual wall sockets. The messenger wire is attached to the pole brackets by a Locke insulator, which is held in place on the brackets by a special iron casting. The trolley is No. 4/0 grooved wire and is suspended from the messenger wire by spreaders of ½-inch iron pipe in varying lengths, depending on the catenary

curve. These spreaders are attached to the messenger wire by 3-prong clamps, and to the trolley wire by 4-inch mechanical

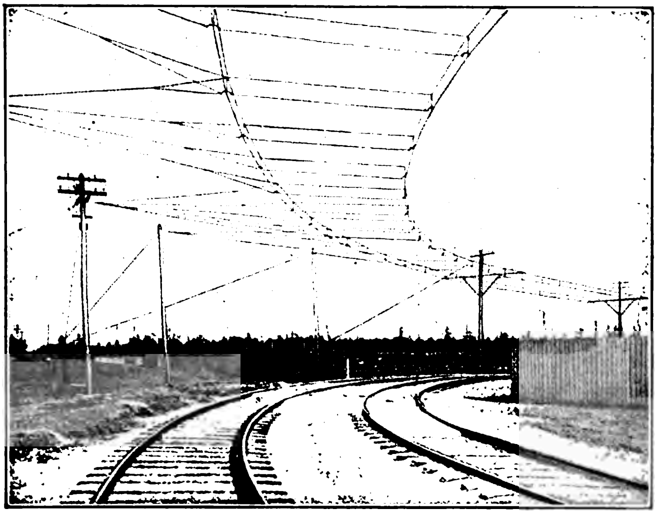


FIG. 41.—Catenary Construction.

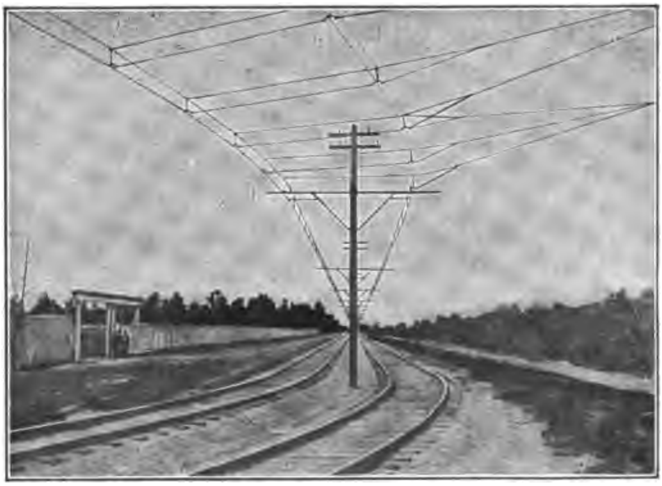


FIG. 42.—Catenary Construction.

clips, the spreaders being provided at both ends with screw threads to screw into the clamp and clip.

At curves, the construction is held in place by single and double pull-offs attached to both messenger wire and trolley wire. The pull-offs from the two wires in each case meet in a common pull-off insulator from which they are carried to the guy pole by a single guy wire. At the beginning of curves, the

Fig. 43.—Catenary Construction on Indianapolis and Cincinnati Line.

construction is further strengthened by means of an iron rod reaching from the bracket brace on the pole out to the trolley wire to which it is attached by a standard clip. Figs. 41 and 42 illustrate the general appearance of the construction.

In a number of localities the catenary construction is now in use for high tension single phase interurban roads. Fig. 43

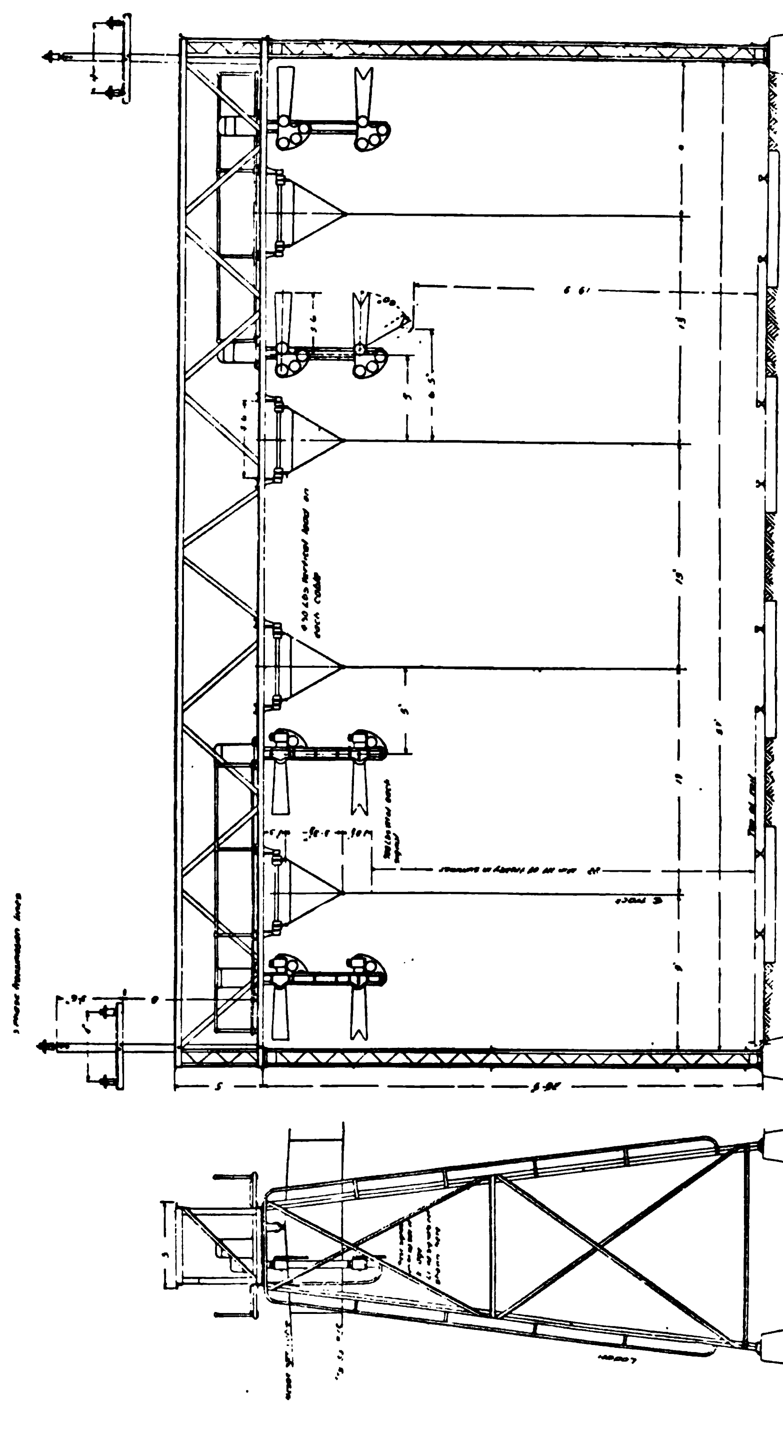


FIG. 44.—Catenary Construction with Bridge Suspension.

illustrates that in use on the Indianapolis and Cincinnati line. In cases where from 3,000 to 6,000 volts are used on the trolley wire special attention must be given to insulators and to the whole strength of the structure. Supports from the messenger wire to the trolley should be spaced 10 feet or 15 feet apart. When properly installed, the trolley wire remains prac-

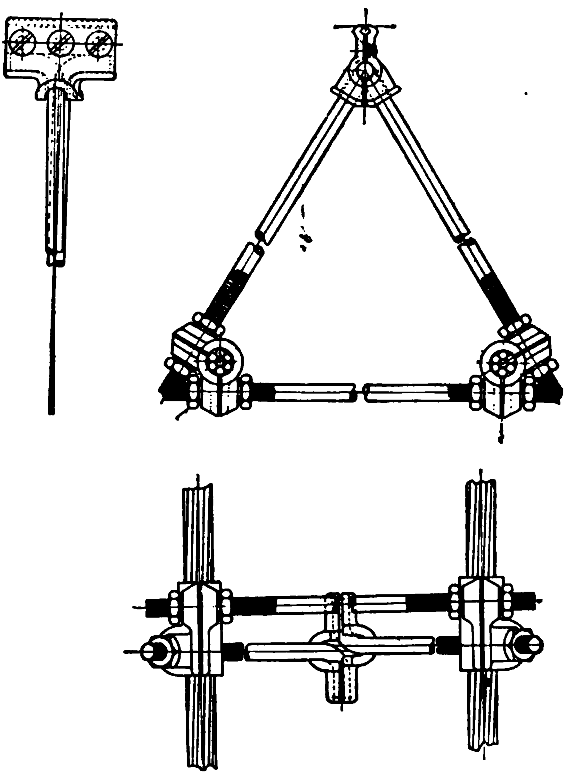


FIG. 45.—Double Catenary Adjustable Trolley Hanger.

tically horizontal at all temperatures and does not bend up and down as the trolley wheel passes under it.

A heavier construction is sometimes necessary, as in the electrification of a steam road, and in such cases there are used two messenger cables in the same horizontal plane while the trolley wire is beneath and midway between them. This forms a triangle, and the supports from both messenger wires

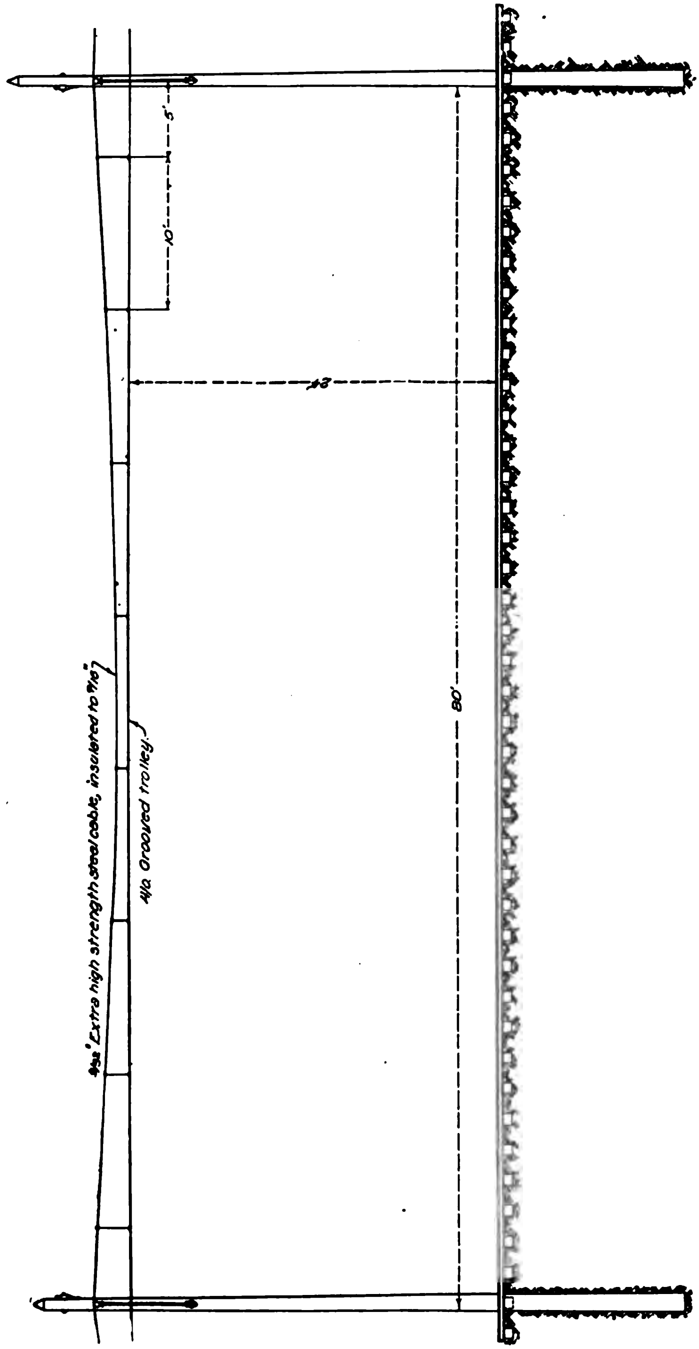


FIG. 46.—Catenary Construction on West Shore Railroad.

tend to stop all side swaying. The so-called "tower" method of supporting the catenary is then usually employed. Steel bridges cross the tracks at intervals of about 300 feet and carry the supporting insulators for the messenger wires. Advantage is also taken of the opportunity of attaching semaphore signals

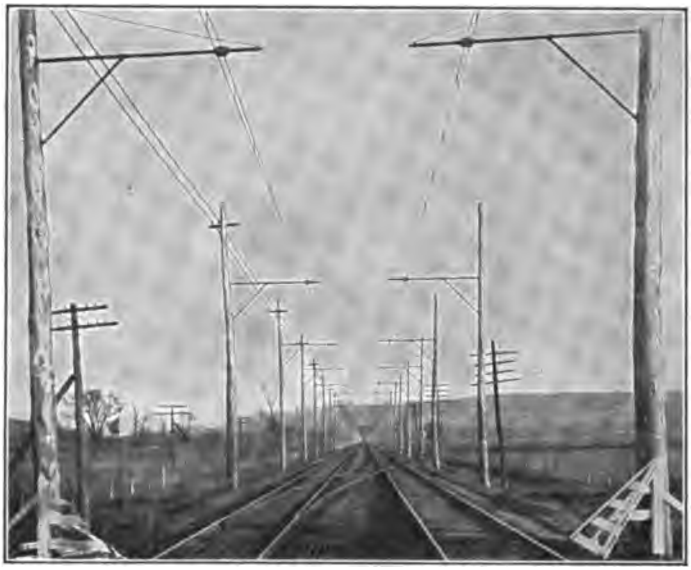


FIG. 47.—Catenary Construction on West Shore Railroad.

to some of these bridges. Figs. 44 and 45 give some idea of this class of construction.

Fig. 46 shows a side view of the catenary construction in use on the West Shore steam road. In this can be seen the catenary curve of the messenger wire and the horizontal position of the trolley wire. Fig. 47 is a photograph of the same construction.

THE THIRD RAIL

This form of working conductor was first employed years ago in some of the earliest experiments with electric locomotives, before even the trolley wire was used, but its first practical application was on the Intramural elevated road at the Chicago World's Fair in 1893. The Chicago elevated roads,

the Baltimore & Ohio Railroad and the New York, New Haven & Hartford then adopted it in turn. It is now employed successfully by a number of interurban roads operating over a private right of way. Numerous advantages are claimed for it over the overhead trolley wire when used under favorable conditions, among which are the following: it can supply a much heavier current to the train than could be obtained from a trolley wire; the difficulty of the trolley wheel leaving the wire is eliminated; the cost of construction, where the conductivity of the low tension system is equal, is less; the cost of

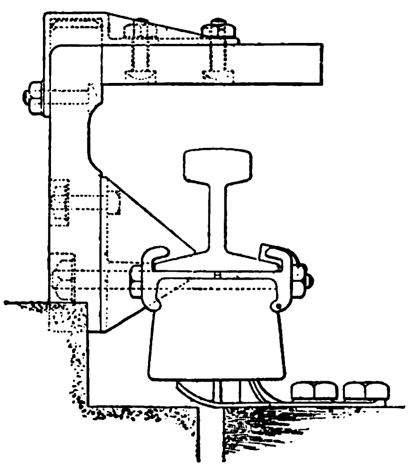


FIG. 48.—Third Rail Guard.

maintenance is much less than that of an overhead wire, in fact it is remarkably low; the first two advantages claimed also render it especially desirable where extremely high speeds are employed. Among its disadvantages are: it can only be used on private right of way, and where cars run through towns or on highways, a trolley wire must be substituted and cars equipped with trolley poles; in its usual unprotected form it is a source of danger to trespassers or animals who may be on the right of way; while snow does not interrupt its operation to any great extent, sleet is very troublesome, although the trolley wire has the same trouble in a lesser degree; it has been claimed that it is difficult to insulate,

but as a matter of fact, no difficulty in this line has ever been encountered.

In recent developments of third rail practice most of these objections have been overcome, or to be more accurate, are expected to be. Nearly all improvements, however, increase

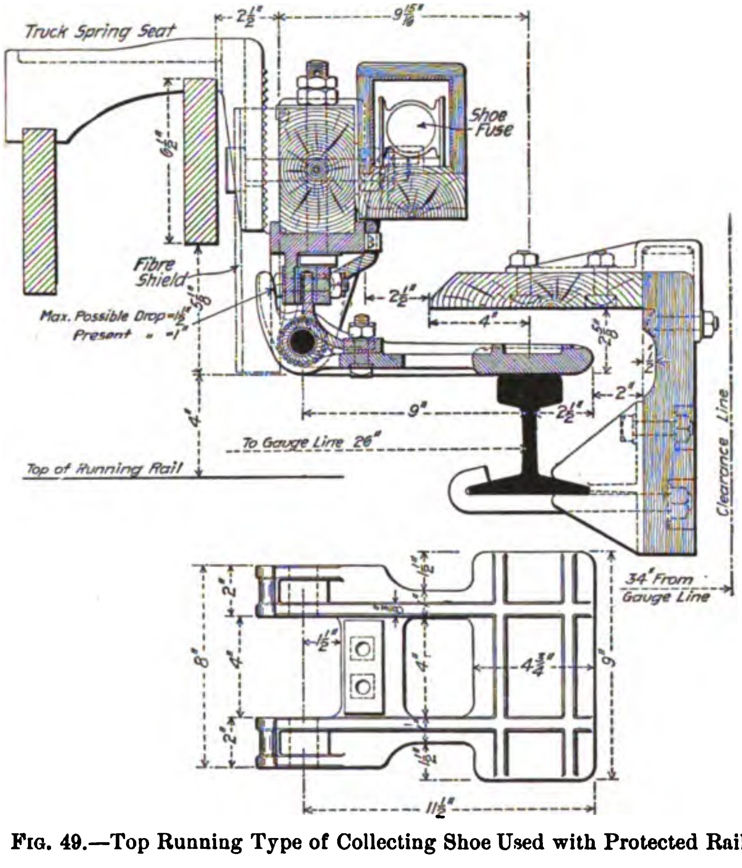


Fig. 49.—Top Running Type of Collecting Shoe Used with Protected Rail.

the cost of construction, and these are no exception. The trouble arising from sleet, and accident from contact with the rail, has been largely eliminated by a protecting guard consisting of a plank 6 inches or 8 inches wide, and 1½ inches to 2 inches thick, supported either from the tie, or from the rail itself, by iron brackets and bolts. The plank is thus held in a horizontal position about 3 inches above the top of the rail.

There is no vertical back piece, except at the supports, for it would form a pocket for drifting snow. One style of this guard is shown in Fig. 48. This form of protection necessitates a change in the ordinary top running type of collecting shoe, and the new type is seen in Fig. 49.

The usual form of unprotected rail has suffered severely in the past through interruptions to traffic caused by sleet. The conditions which produce this are usually those in which rain freezes as soon as it strikes the colder rail. This causes a

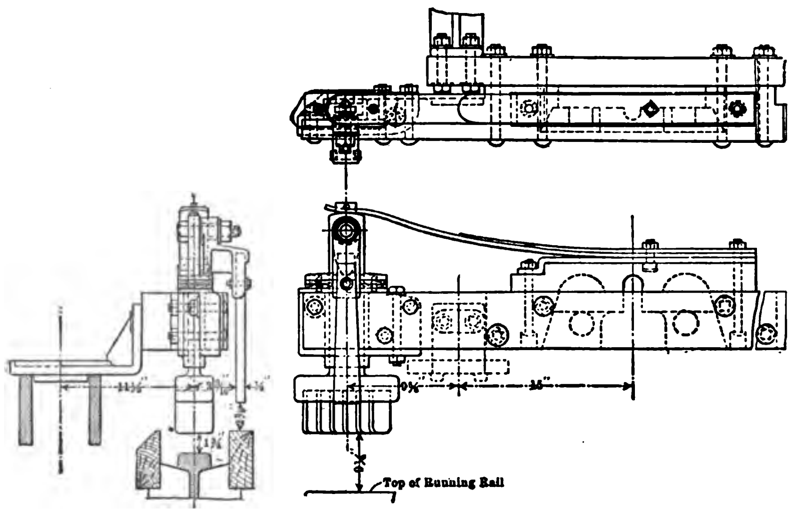


FIG. 50.—Sleet Brush Used on Manhattan Elevated.

thin coating of ice to form on the rail which is exceedingly difficult to remove. A solution of hot water and salt has been tried on some elevated roads, where it is applied to the rail from a car through a pipe, but this has serious objections on an interurban line due to the liability to decrease the insulation resistance. The Aurora, Elgin & Chicago Railway and some others are said to have successfully employed a solution of calcium chloride in the same manner. The third rail lines of the New York, New Haven & Hartford Railroad have employed a powerful form of cutter, or scraper, very successfully. This is a single blade of tool steel forced vertically down on the rail by means of levers under considerable pressure. Another form,

which more nearly resembles a group of scrapers, forced down by spring pressure, is used by the Manhattan Elevated and by

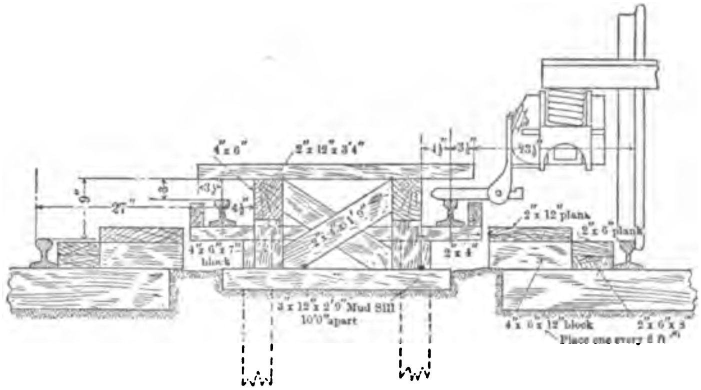


FIG. 51.—Plan of Carrying Third Rail through Stations, North Shore Railway, San Francisco.

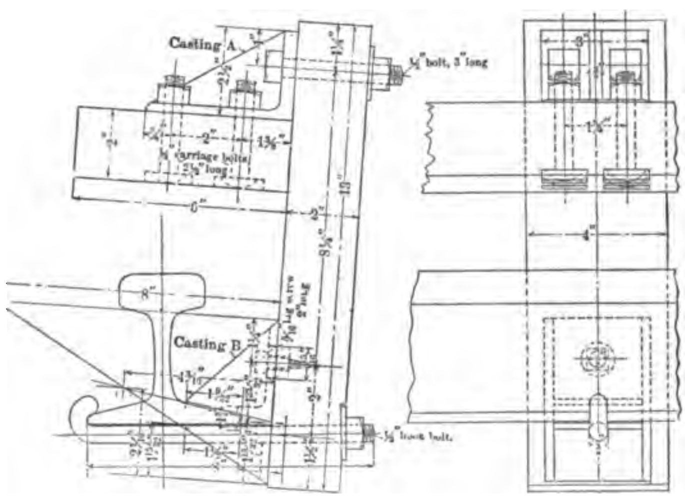


FIG. 52.—Protection of Third Rail in the Open, North Shore Railway, San Francisco.

some of the Chicago elevated roads. It is shown in detail in Fig. 50.

A form of conductor rail with its protecting guard, together with the style of collector shoe used on the Subway Division of the Interborough Rapid Transit Co., is shown in Fig. 49.

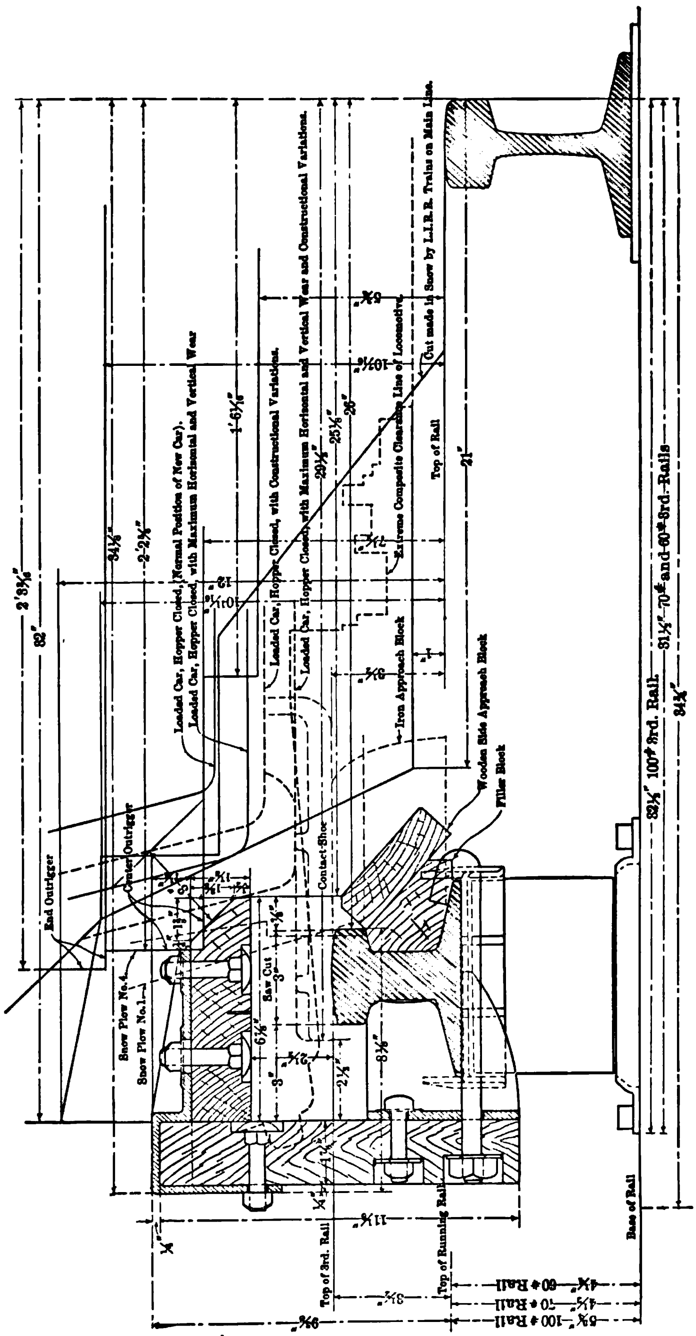


FIG. 53.—Third Rail Protection on Long Island Railroad.

This represents one of the more recent developments in third rail practice.

A plan of carrying the third rail through stations showing platform construction, employed by the North Shore Railway of San Francisco, Cal., is shown in Fig. 51, and Fig. 52 gives the style of protection for the rail in the open.

The adoption of the third rail in the electrification of the surburban service of some of the large steam roads has given an impetus to its development. The most recent of these to be

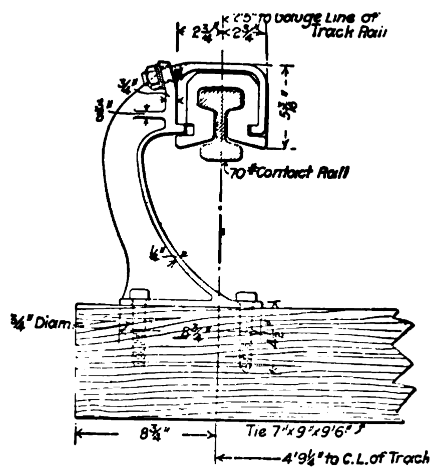


FIG. 54.—Type of Third Rail Used by New York Central.

placed in operation is that of the Long Island Railroad. Their plan of third rail location and its protection is shown in Fig. 53.

The New York Central have made a considerable departure from current methods in the adoption of an underrunning contact rail. This does away with the protecting plank and makes it possible to protect the rail on all sides except the bottom, by a sheathing of wood. It also permits the use of an improved form of insulator. The details of this construction are shown in Figs. 54 and 55.

That there are certain advantages in this form of construction is obvious. If the sheathing is brought down on the sides in such a manner as to prevent rain from collecting and drip-

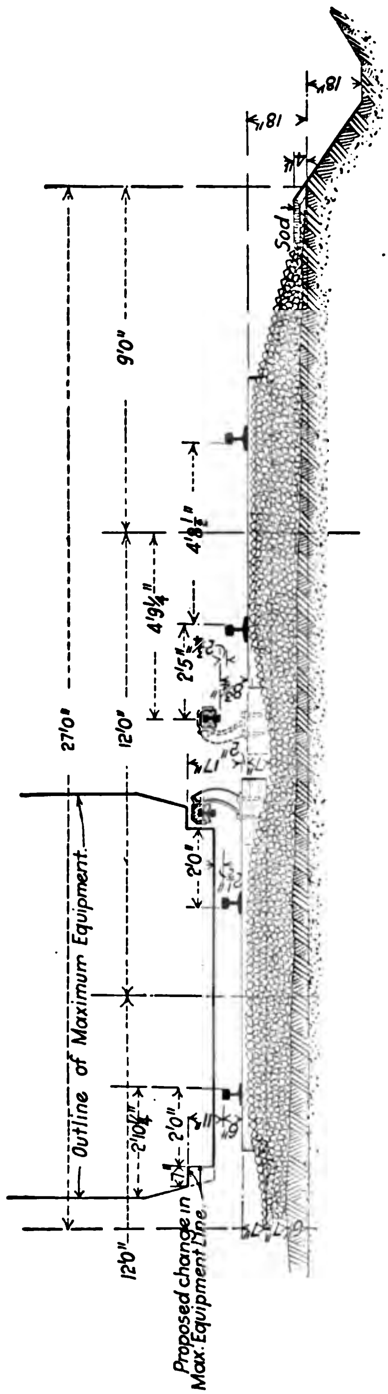


FIG. 55.—Half Cross-Section of Four-Track New York Central Lines.

ping from the contact surface, the trouble arising from the water freezing on it would be overcome. It is possible that a slight shock might be felt from the sheathing during very wet weather, but if so, it would doubtless be harmless.

The necessity for a standard position for the contact rail with reference to vertical height, and horizontal distance from the gauge line of the service rail, is becoming more and more important. This becomes an absolute necessity if interchange of cars is contemplated. Steps are already being taken by the steam roads toward this end, in the vicinity of New York. In

FIG. 56.—Typical Third Rail Line with Unprotected Rail.

the future interurban roads will have to give it serious consideration. A few of these distances now in use are given below:

	Height above Service Rail. Ins.	Horizontal Distance. Ins.
New York New Haven & Hartford	1	Center
Aurora, Elgin and Chicago	$6\frac{5}{16}$	$20\frac{1}{8}$
New York Central	$2\frac{3}{4}$	29
Long Island	$3\frac{1}{2}$	27
Interborough Rapid Transit	4	26
Manhattan Elevated	$7\frac{1}{2}$	$20\frac{3}{4}$
Boston Elevated	6	$20\frac{5}{8}$
Brooklyn Elevated	6	$22\frac{1}{2}$
Chicago Elevated	$6\frac{1}{2}$	$20\frac{1}{8}$
Albany and Hudson	6	27

Fig. 56 shows a typical view of an interurban third rail line with an unprotected rail.

The New York, New Haven & Hartford Co.'s third rail laid in the center of the track on creosoted wooden blocks for insulators, gave some remarkable results as regards insulation. The average measured leakage was but little over one ampere

FIG. 57.—Operation with the Third Rail Submerged in Water.

per mile and it was considered that most of this occurred in the underground cable work, connecting breaks in the rail at road crossings and switches. Curious results were experienced when the track became flooded by a freshet.

Figs. 57 and 58 are photographs showing a section of about half a mile, in which the conductor rail is practically under water. A remarkable fact is that the service was not even

Fig. 58.—Operation with Third Rail Partially Submerged in Water.

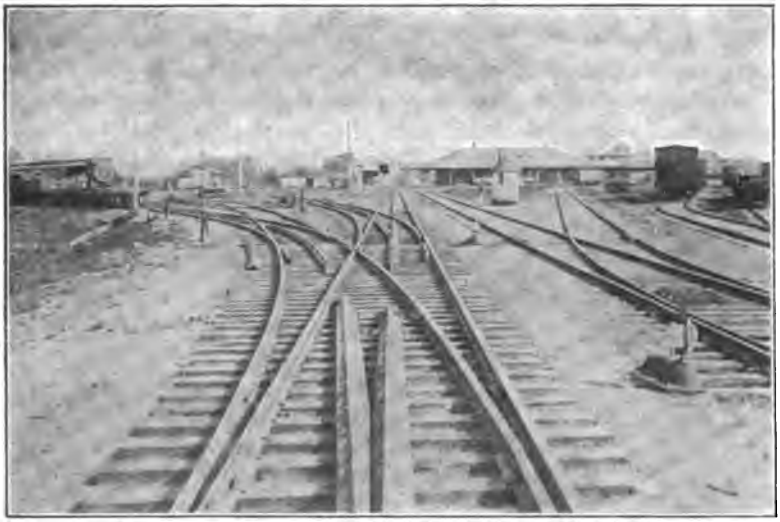


Fig. 59.—Third Rail Construction of N. Y., N. H. & H. R. R.

interrupted while the cars were running through the place for several hours before it subsided. The additional load on the power station was estimated at about 400 amperes at 650 volts, but little more than that required by one regular train.

In joining the gaps in third rails at highway crossings, the usual underground connections have been a source of trouble due to leakage especially at the entrance and exit from the

FIG. 60.—Third Rail Construction of N. Y., N. H. & H. R. R.

ground. Several western roads have made these connections overhead with much better results and at no greater expense.

Figs. 59 and 60 are examples of the third rail construction of the New York, New Haven & Hartford Railroad.

CURRENT COLLECTING DEVICES

This subject, as applied to railway work, is assumed to mean the various methods and apparatus used to transmit the electric current from the working conductor to the motor car. It may be said that there are only three methods in general use: the underrunning trolley wheel with its pole and base; the third rail shoe and its support, in several forms; and the underrunning bow trolley which, though widely used abroad, has not been much used in this country as yet, due to our em-

ployment of heavier currents, and to other conditions, under which the trolley wheel has been more successful.

The performance of the standard trolley wheel has been somewhat of a surprise with the advent of heavy currents and high speeds. The area of contact with the trolley wire is so small that it was naturally expected to give serious trouble from arcing. But its ability to conduct several hundred amperes across the contact is undoubtedly due to its motion, which continually dissipates the heat throughout the wheel and along the wire. Otherwise, if the same current were transmitted while the wheel was stationary, it would become welded to the wire in a few moments.

While apparently few changes have been made in the design of the trolley wheel, harp, pole and base for many years, certain steps have been taken to enable the apparatus to keep pace with the general advance in the art. The principal difficulty when higher speeds came into use was to keep the wheel from frequently leaving the wire. This was sometimes so serious as to cause doubt as to the advisability of continuing its use. As evidence of this a number of years ago one of the high speed interurban roads running out of Cleveland, Ohio, on private right of way, made an investigation of the third rail system with a view of changing, on account of the trouble above mentioned, and the high cost of maintaining the trolley wire. The many improvements in overhead construction, including the use of the flexible suspension on brackets, and of grooved or figure eight wire, together with the addition of trolley catchers, or retrievers on the cars, have done much to keep the wheel on the wire, and prevent damage. At the present time few of the larger interurban roads have any complaints to make on that score.

The groove of a trolley wheel is so designed that at the angle the wheel will take on the car passing around curves its flange will not strike or bind on the wire, which would tend to force the wheel off the wire.

Iron trolley wheels have been used, and wheels with brass centers and iron flanges. They have been put on the market from time to time but have not met with favor in practice, as they pit and wear the trolley wire faster than the ordinary composition wheel on account of the greater heating effect of

the arc between the iron of the wheel and the copper wire. Their use has been discontinued.

The limit to the carrying capacity of the trolley wheel is now well known.

A motor car hauling a heavy train, with one trolley wheel on a No. 4/0 figure eight wire, necessitating a current consumption of from 500 to 600 amperes at 600 volts, will show continual, but not severe arcing at the contact. The wear on the wheel because of the arc, is serious, and its life is short. In general, safe practice is considered 250 amperes operating current, and 600 amperes accelerating.

The potential drop between the trolley wheel and the wire increases with the speed of the car. With a constant current of 100 amperes it ranges from 12 volts to 28 volts at 15 miles per hour and in one case it was 45 volts with a current of 200 amperes at 45 miles per hour.

This drop can be readily measured on a car with poles at both ends, by placing both poles on the wire and disconnecting one trolley base from the car circuit, and placing a voltmeter in the break, with one terminal on the base and the other on the car circuit. It will then be directly across the contact of the other trolley wheel with the trolley wire, as the two trolley bases are connected together. The potential differences at various currents and speeds can then be readily determined. Wheels with ruts or grooves show considerable more drop than new wheels, and if the energy lost by these wheels were taken into consideration they would be discarded before their mechanical usefulness was gone.

The life of a trolley wheel in ordinary service is limited by a number of conditions. The wear on the wheel is chiefly mechanical, except in sleet storms, and it depends on the proper construction and maintenance of the trolley wire, the speed, and the tension on the pole. So in city service the mileage may be quite high, due to the low speed. In interurban service the wear is often severe. In consequence of the greatly varied conditions to be found, the life of trolley wheels on different systems varies within wide limits. On one system, consisting of city and suburban service, where conditions were perfect: such as well balanced wheels of proper composition; good overhead work; proper tension, and a freely turning stand, a mileage

of from 35,000 to 40,000 miles has been attained, but under average conditions the same road shows about 25,000 miles. This is undoubtedly a high record. On one of the largest high speed interurban systems a 6-inch wheel gives from 5,000 to 7,000 miles. In city service the usual practice is to use a wheel 4 inches in diameter, and on interurban service 6 inches, but there are systems which use the 6-inch wheels in both..

As to which is the best composition for a trolley wheel, opinions differ somewhat. The conductivity of the mixture is not of so much importance as a proper degree of hardness. If too hard, the wear on the wire will increase, and renewal of trolley wire is far more expensive than wheels. On the other hand, if the wheel is too soft its life will be shortened. One recommended composition is 90 per cent. copper, 6 per cent. tin, 3 per cent. zinc, and 1 per cent. lead.

The fact that the bearing of a wheel wears out before the rim, has compelled the use of bushings for bearings, thus permitting the renewal of the bushings as long as the wheel can be used. Most bushings have graphite inserts on the bearing surface to assist in their lubrication. The hub of the wheel sometimes contains a recess for oil, which is conveyed to the bearing in several ways.

The malleable iron harp, with its steel pin which is kept from turning by cotter pins in recesses on the outside, and the copper or phosphor bronze spring contacts pressing against the hub of the wheel, has apparently undergone no radical change for many years.

Attachments for quickly removing the harp from the pole, such as a taper socket with lock nuts, are not improvements in the right direction, as they increase the weight and complication. The shank of the harp pinned and riveted in the trolley pole is the usual and accepted method. In considering any change on the trolley wheel end of the pole, it should be remembered that every ounce of weight added here increases the arcing between the trolley wheel and the wire at every hanger, and where there is a sudden change in the alignment of the wire.

The tapering, hollow steel poles do not vary except in length, but in some cases are replaced by wood. In some parts of the West a very light strong pole is made from second growth

hickory. They are very satisfactory in both city and interurban service and are much used where such wood is easily obtainable.

The trolley base or stand has also been through but few changes and seems to have developed no serious faults. It is desirable that it should rotate easily, which tends to keep the wheel on the wire at curves, and it should not occupy any more height than necessary, on account of the small headroom under overhead bridges. Some trouble has been experienced in some places due to the "fatigue" of the springs. This is generally caused by keeping the pole tied down, or on a low wire, in car houses. This keeps the springs in constant tension or compression and the resiliency is lost when the wheel reaches a high wire, as on steam railroad crossings. In consequence,

FIG. 61.—Trolley Wheel.

the springs fail to lift the wheel high enough, and contact is lost. The remedy for this is to relieve the springs whenever the car is in the house, or out of service, by letting the pole rise to its greatest height and leaving it so, instead of tied down. Particular attention should be paid to the adjustment of the tension and it ought to be frequently tested. This is easily done by attaching an ordinary spring balance to the rope and allowing the wheel to rise to a height corresponding to that of the wire. The reading of the scale then gives the tension. For ordinary city service the general practice is to use 18 pounds, while on high speed interurban service, with 6-inch wheels, 35 pounds is usually employed.

Fig. 61 shows one form of trolley wheel, and Fig. 62 a form of harp in common use. Fig. 63 illustrates the latest forms of

the union standard trolley bases. In these it will be noticed the springs are in compression.

The third rail collector shoe, in what may be termed its original form, is still in use on a number of roads which employ an unprotected contact rail, including most of the elevated roads. In this form the shoe is hung by a pair of slotted links, placed at an angle to each other, attached to a support in the center of a wooden bar, which extends from one journal box to the other. The shoe has a rise and fall of about one inch and the contact pressure is that due to its weight. It is necessary that the shoe be supported, in this case at least, either from the journal boxes, or the equalizer bars of an M. C. B. truck, for these are the only parts of the truck which do not move with the springs, but follow the track rigidly.

On one interurban road cast iron shoes of this type 14 inches long, 5 inches wide, weighing 15 pounds have frequently

FIG. 62.—Trolley Harp.

run three months, making from 30,000 to 40,000 miles in summer weather. In winter, especially when snow or sleet is frequently encountered, their life is sometimes only two weeks, and at such times they may become red hot from the arcing they are subjected to.

Under the section entitled "The Third Rail," Fig. 49 shows the shoe now generally employed when running on top of a protected rail. As will be easily seen, this shoe projects from the truck under the plank covering the rail, and the contact pressure is increased beyond that due to its weight by a spring. It is used on a number of interurban lines, as well as on the Long Island Railroad and the New York Subway. The type of collector shoe to be used on the underrunning protected contact rail of the New York Central is very similar, the spring pressure acting to force the shoe upward, instead of down-

ward. The Boston Elevated, after some experiments, abandoned the original form of link suspended cast steel shoe, and substituted that illustrated in Fig. 64, the details of which are seen in Fig. 65.

This is another case where spring pressure is substituted for

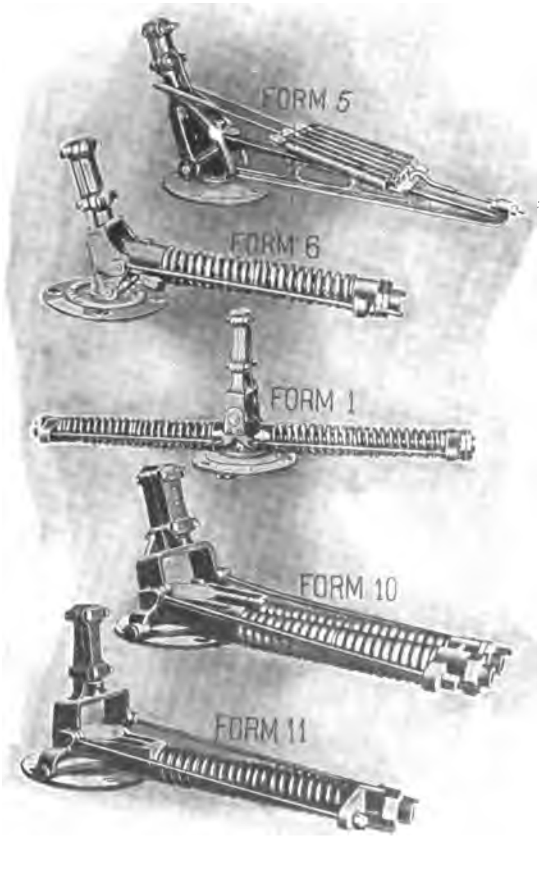


FIG. 63.—Latest Forms of Union Standard Trolley Bases.

gravity in making the contact. Its construction is plainly shown in the cuts. The steel shoe is a flat bar of soft steel which, before it is bent into the shape shown, measures 23 inches long,

$3\frac{1}{2}$ inches wide, and $\frac{1}{2}$ inch thick, and weighs $10\frac{1}{2}$ pounds. Owing to the manner in which it is held the shoe appears to be pushed instead of pulled, and has a tendency to tilt forward, increasing the contact pressure. The elliptic spring gives a downward pressure of 50 pounds, which added to the weight of the shoe produces a pressure of $60\frac{1}{2}$ pounds. The shoe readily follows any irregularity in the rail and does not jump at joints, or approach blocks, when taking new sections. This tendency of the shoe to cling to the rail eliminates nearly

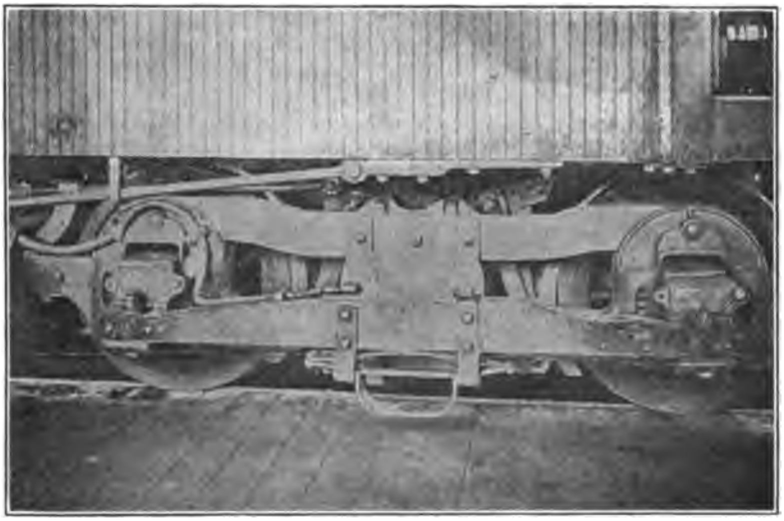


FIG. 64.—Steel Shoe Used on Boston Elevated.

all sparking between the surfaces. These shoes have a life of about 13,500 miles and are much more effective in ice and sleet than the old form.

Other methods of conducting the current from overhead wires to the car than by the use of the trolley wheel, have frequently been tried in this country. Fig. 66 is a form of bow trolley adapted for high tension single phase railways in this country, and is operated and adjusted by compressed air. It is a modification of the well-known Siemens-Halske bow trolley, which is widely used in Europe on both continuous current and alternating current roads with success under the existing conditions. These conditions seldom include high speed and the volume of current collected rarely approaches

200 amperes, being generally nearer 100. Its failure to supersede the trolley wheel in this country is simply due to the more severe conditions. Its great advantage is that it cannot leave the wire, and if the wear on the "bow string" were not excess-

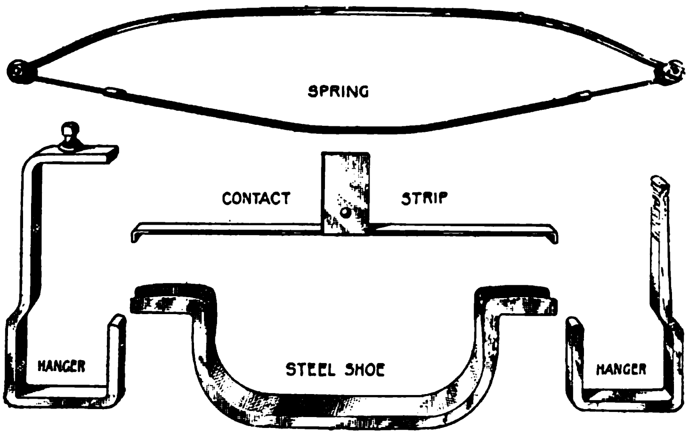


Fig. 65.—Details of Shoe Used on Boston Elevated.

Fig. 66.—One Form of Bow Trolley Used on High Tension Single Phase Railways.

ive, due to arcing and speed, it might be successful. However with the opening of high tension single phase lines in which the current collected is small in volume, it is very probable that this style of current collector, in a modified form,

will come into general use. If the contact wire of the bow can be made to give a reasonable life, the cost of renewing it will become less than the trolley wheel.

Fig. 67 shows a form of bow trolley designed for a high tension single phase locomotive built in this country. The vertical elongation of the diamond shaped bow is effected by a compressed air mechanism in the base. The contact bar is thus readily raised to the wire, or lowered as desired. Another device said to be in use in a few localities consists of a

FIG. 67.—Heavy Service Locomotive with Pantagraph Bow Trolley.

roller about 2 inches in diameter and about 3 feet long. The roller is a cylinder of composition and rotates in ball bearings carried on the ends of a wide fork, or by two arms extending to the roof. One form of this collector was tried on an eastern road, using heavy currents, some years ago, but was unsuccessful owing to severe arcing.

Whatever the form of collector its principal features should be lightness, non-arcing, long life, and it must not impose great wear on the working conductor.

CHAPTER VI

TIME TABLES AND SCHEDULES

TIME TABLES

THE time table of an interurban road is the general law governing the arriving and leaving time of all scheduled trains, at all sidings or stations. It is obtained from the speed schedule adopted, as found by laying out each train as a line, on a sheet having distances, with stations and sidings to scale on the vertical side, and time on the horizontal.

A sample time table is shown below, which is issued for the guidance of employees. This is the usual form adopted by steam roads and includes other information regarding signals, speeds allowed at various points, and the rights of different classes of trains over one another. Few interurban roads go to the trouble of issuing these time tables, but that it is a good practice is generally conceded.

No. 81. THE X, Y, AND Z RY. June 30, 1905.

OFFICIAL TIME TABLES. FOR EMPLOYEES ONLY.

			Local	Local	Local	Local	Express	Local
Train Number....................			2	4	6	8	10	12
Stations.	Siding No.	Mileage	Note A.M.	D. A.M.	D. A.M.	D. A.M.	D. ex.S. A.M.	Note A.M.
Xenia	6	0	8:20	8:50	9:20	9:50	10:00	10:20
Trumbull...........	8	1.8	8:28	$\boxed{8:58}$	$\boxed{9:28}$	$\boxed{9:58}$		
Danville............	10	3.0	8:35	9:05	9:35	10:05	10:10	
N. Y. C. Junction...	11	3.44	8:37	9:07	9:37	10:07		$\boxed{10:31 \; 10:33}$
Oldtown............	13	5.4	$\boxed{8:43}$	$\boxed{9:15}$	$\boxed{9:43}$	$\boxed{10:15}$		10:40
Fullerton	20	7.4	8:50	9:22	9:50	$\boxed{10:22}$	$\boxed{10:22}$	10:47
Youngstown	21	11.0	9:04	0:36	10:04	10:36	10:30	11:01

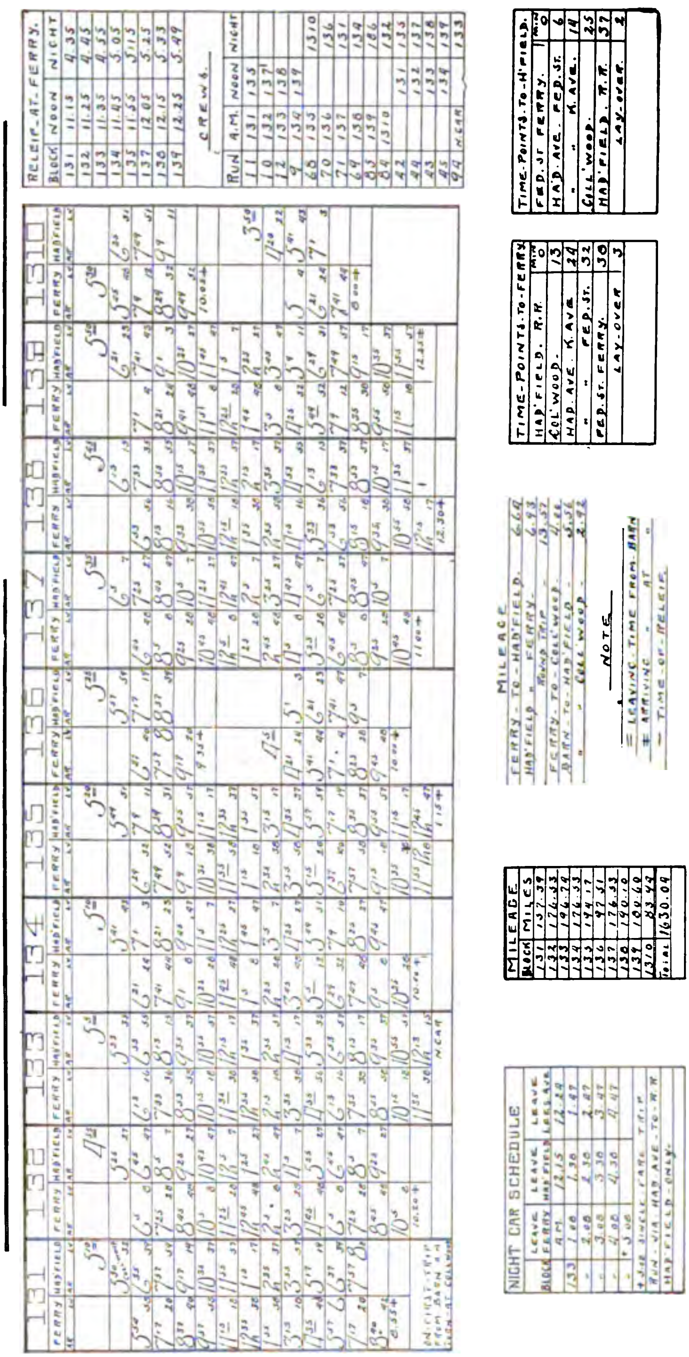
Note—No. 2 runs daily, but does not stop at N. Y. C. Junction on Sundays.
Note—No. 12 runs express to N. Y. C. Junction daily except Sundays.
Note—Places where time is given in figures enclosed by black lines are regular passing points.

The time table of a city system, while it is essentially the same as the interurban in principle, is much more cumbersome, requiring so many runs and cars, and sometimes frequent alterations. Such a time table is of interest only to employees and is seldom printed. It is either written up with chalk on a blackboard in each car house or with a pen on a special sheet hung up in a frame. A sample city and suburban time table is shown on page 110. Below is shown a table giving the time required to run 1 mile, at speeds from 5 to 60 miles per hour. This is very useful to all motormen, for it enables them to easily time their speed if distances are known.

TABLE XXIII

TIME REQUIRED TO RUN 1 MILE AT SPEEDS FROM 5 TO 60 MILES PER HOUR

	Time Running One Mile.			Time Running One Mile.	
Miles Per Hour.	Min.	Sec.	Miles Per Hour	Min.	Sec.
5	12	00	33	1	49.1
6	10	00	34	1	45.9
7	8	43 8	35	1	42 8
8	7	30	36	1	40
9	6	40	37	1	37.3
10	6	00	38	1	34.7
11	5	27.3	39	1	32 3
12	5	00	40	1	30
13	4	36.9	41	1	27.8
14	4	17.1	42	1	25.7
15	4	00	43	1	23.8
16	3	45	44	1	21.8
17	3	31.8	45	1	20
18	3	20	46	1	18 2
19	3	6.5	47	1	16.6
20	3	00	48	1	15
21	2	51.4	49	1	13.5
22	2	43.6	50	1	12
23	2	36.5	51	1	10.6
24	2	30	52	1	9.2
25	2	24	53	1	7.9
26	2	18.5	54	1	6.7
27	2	13.3	55	1	5.5
28	2	8.6	56	1	4.3
29	2	4.1	57	1	3.2
30	2	00	58	1	2.1
31	1	56.1	59	1	1
32	1	52.5	60	1	00


HADDONFIELD DAILY
RELEIF AT FERRY.
BLOCK NOON NIGHT
131 11.15 4.35
132 11.25 4.45
133 11.35 4.55
134 11.45 5.05
135 11.55 5.15
137 12.05 5.25
138 12.15 5.33
139 12.25 5.49
CREWS.
RUN A.M. NOON NIGHT
NIGHT CAR SCHEDULE
MILEAGE
BLOCK MILES
131 137.39
132 176.33
133 194.79
134 176.33
135 194.17
136 97.51
137 176.33
138 190.10
139 180.60
1310 83.42
TOTAL 1630.09
MILEAGE
FERRY - TO - HAD'FIELD. 6.64
HAD'FIELD - FERRY. 6.93
ROUND TRIP 13.57
FERRY - TO - COLL'WOOD. 4.66
BARN - TO - HAD'FIELD 5.56
" - COLL'WOOD 2.92
NOTE
= LEAVING TIME FROM BARN
‡ ARRIVING " AT "
— TIME OF RELEIF.
TIME-POINTS-TO-FERRY
HAD'FIELD. R.R. 0
COL'WOOD. 13
HAD. AVE. K. AVE. 24
" " FED. ST. 32
FED. ST. FERRY. 30
LAY-OVER 3
TIME-POINTS-TO-H'FIELD.
FED. ST FERRY. 0
HAD. AVE. FED. ST. 6
" " K. AVE. 14
COLL'WOOD. 25
HAD'FIELD. R.R. 37
LAY-OVER 2

In a medium size city system it is desirable to issue a small time table of convenient size for the public, giving the names of the city lines, and the time the first and last car of the day leaves a central point. Also the headway between cars in rush hours, as well as at other times, and the schedule time to the end of each line. Information can also be given here of the time of extra cars put on for meeting certain trains, boats or for carrying theater goers. Some managers believe that the public are better satisfied if they do not have to consult a time table, provided the cars are frequent enough so that only a short wait is necessary at any time of the day. They say this applies as well to an interurban road which runs its cars from the terminals at regular intervals, as hourly or half hourly.

For interurban roads in general, operating local, as well as through limited trains, whether the intervals are regular or not, it is a good policy to issue a neat folder for the public giving the schedule time of all trains with their numbers, separating the weekday from the Sunday schedule, and various rules of the company, regarding rates of fare, the transportation of trunks, and other baggage. An opportunity is also given in the folder to describe the various points of interest along the line, as well as in the towns through which it passes. Particular care should be taken in arranging the time table, to put it in as simple and intelligible form as possible. It is well known that some steam roads issue time tables which are little better than Chinese puzzles to the ordinary traveler. The patrons of an interurban road living along the line soon commit the time table to memory, and only need it when changes are made, but to the stranger it is of great convenience.

Train Operation

The schedule speed must be more or less approximately determined before the road is constructed, as on it depends the character of the track construction, and the equipment of the cars, transmission line, and power station. On single track lines the location of the sidings, or turnouts, determine it absolutely, when operating a full schedule. A half-hourly service from the terminals means a passing point every fifteen minutes, and the speed of the trains determines the distance

between such points. If this is local service, and if a few higher speed limited trains, with few stops, are operated at the same time, the limit of safe operation, aided by efficient despatching and block signals, has been reached for a single track road. As most interurban roads of the present day are single tracked, it is hardly necessary to discuss the difference in operation of a double tracked road. It may be easily seen, however, that the whole schedule speed question is simplified in the latter case.

The principal difficulty confronting most interurban roads is the question of maintaining the regular schedule during periods of congested traffic. There are times on every road when a large number of people want to be carried to their destination at the same time. This overcrowds the regular schedule and it becomes necessary to increase the number of cars. Usually the only resource is to put on extra motor cars and run them as extras, or as the steam roads say, on a "wild cat" schedule, taking orders at every point from the despatcher. Another way is to run several cars as sections of a regular train, passing them through the signal blocks as one train. This plan is very frequently resorted to although often done without any system, dependence being entirely placed on the train crews, who notify those waiting to pass that other cars are following them through the block. These methods are fairly safe provided orders are carefully obeyed, but almost surely there is a loss of time, and the whole schedule is demoralized until the rush is over. A time table arranged for normal traffic is of little use in such an emergency, and instead the cars become spaced by distance. In the case of cars following one another, the distance between them is determined by the motorman, who is supposed to use every precaution in his power. On modern steam roads, both time and distance are used to determine the space between trains; the time table providing the former, and the signal blocks the latter. Under normal conditions of traffic, the time table and the despatcher are all that is necessary, but as soon as the schedule becomes disarranged, and trains begin to move faster or slower than the normal, then the distance spacing of the signal blocks enables the train service to recover itself quickly, and at the same time handle a greatly increased traffic.

Abstract from rules for train operation of the Cincinnati, Dayton & Toledo Traction Co.:

BLOCK SIGNALS TO BE USED BY MOTORMEN AND CONDUCTORS

42. Signal lights must be used in running between all switches where the same are provided, unless otherwise ordered by the despatcher. If for any reason the signal lamps are not working, you must not proceed without orders from the despatcher to do so, excepting as follows:

A. Regular Trains.—If for any reason you cannot get the despatcher by 'phone, you will proceed on regular schedule, passing regular trains at schedule passing points, and notify the despatcher of the trouble as soon as possible.

B. Extra Trains.—If for any reason the signal lamps are not working and you cannot get the despatcher, you must wait for the next regular train, and run as second section to the regular train, until you can get orders from the despatcher.

C. Work trains will be permitted to work between switches without signal lights only on orders from the despatcher.

D. Work trains, when working between switches near a curve or any place where your car cannot be clearly seen for a distance of 1,000 feet, 10 poles each way, the conductor of the work train must go at least 10 poles in the direction from which the next car is due and flag the approaching train.

SIGNALS TO BE USED BY TRACK, BRIDGE AND LINE MEN

43. The following rules and signals must be used and observed by trackmen, bridgemen and linemen for the protection of all, whenever work is being done upon track, bridge or line.

Two sets of signals shall be used. One to indicate danger; the other to indicate caution. The signal shall in every case be displayed 1,000 feet (10 poles) on either side of the point at which the workmen are engaged.

A. A red flag by day and a red and white light together, or either one alone placed between the rails, at night will indicate danger, and all trains must be brought to a complete stop when these signals are displayed. A train brought to a stop by those signals will not proceed until the signals have been removed by some authorized person.

B. A red flag by day and a red and white light, or either one

alone by night placed at the right side of the track, will indicate caution, and whenever those signals are displayed all trains must immediately be brought under perfect control and proceed cautiously, expecting to be stopped at any time, until they have passed a similar signal.

CLASSIFICATION OF TRAINS

44. All trains are designated either as regular or extra. All regular trains are scheduled on time table, and one or more cars carrying a marker will be considered a train or section of a train. Each section of a train, except the last, must carry the proper signals to indicate that a train is following.

45. Extra trains are not shown on time table, and they have no rights except those given them by train despatcher.

MOVEMENTS OF TRAINS

46. All scheduled trains have equal rights to scheduled meeting points, and all sections of trains have equal rights, unless otherwise provided by order.

47. No train will leave a station or siding before the time set for it, or without a signal from the conductor.

48. Extra trains must not be run without orders from the despatcher.

49. Extra trains must clear the time of scheduled trains by two minutes except at meeting points made by order.

50. All trains will report to train despatcher before leaving terminal stations, also at meeting points if opposing train is not there.

51. (A) Crews on trains unable to make schedule time must report to despatcher at once.

(B) Crews on trains running late and passing on sidings other than regular schedule passing sidings must report to despatcher where passing opposing trains unless otherwise ordered.

52. All trains must come to a full stop before crossing any steam railroad tracks, and conductor must go ahead and look up and down steam railroad tracks to see that no steam train is approaching before he signals his train across. Motorman must not start his train until he receives a signal from the conductor.

53. All trains must stop before crossing a switch at the intersection of two or more of this company's lines, or at the intersection of the lines of this company with those of another electric railway, and the motorman must not start his train until he receives a signal from the conductor to do so.

54. The first train reaching meeting siding must take siding for opposing train.

55. All trains will approach meeting points under perfect control, and must not attempt to pass until signals and switches are seen to be right and train taking siding is known to be into clear.

56. Conductors and motormen will be held equally responsible for adjustment of switches used by them.

57. The headlight must not be cut out or concealed when taking siding to meet another train until after the train clears the main track or when standing to clear at the end of double track or at a junction point.

Headlight must be exposed at all times when not clear of main track.

58. (A) All interurban trains must report to despatcher at terminal stations and sidings Nos. 30 and 61.

(B) All trains entering on or leaving branch lines must report to despatcher at junction.

(C) Where a layover is had the crew must report when arriving and before leaving unless otherwise ordered.

59. No excuse of any kind will be accepted for passing switches ahead of time.

60. Train must not be run backward for any great distance without turning trolley.

EXTRA TRAINS

61. All trains not represented on the time card are termed "Extra," and must carry a white signal.

62. When regular trains are running late, under no circumstances must extra trains proceed into a block until notified to do so by the despatcher.

63. Should an extra train meet a regular train on regular schedule passing siding, extra must release block in rear, and both regular and extra crews call the despatcher for orders.

64. Should extra train come to a siding where it should pass

a regular train, and the regular is not blocked in, extra crew must release block in rear and call up despatcher for orders. If you cannot get the despatcher by 'phone, lie there until regular comes up going in same direction, and run as second section to destination.

65. If for any reason a train may be lying on the siding and not using the signal lights, the crew must watch signals very closely and notify crews on trains passing that siding, if signal light is against them.

Both motorman and conductor on waiting train will be held equally responsible for the observance of this order.

WORK TRAINS

66. Work trains have no right on main line, except those given by the despatcher, and must clear the time of all regular trains.

Another method which is becoming more popular among railway managers for various reasons is the coupling of one or two light trailers to the regular motor car, in both city and interurban service. This saves operating expense in wages of motormen, if not in conductors, for usually a conductor to every car is necessary. With adequate coupling arrangements, air brakes on every car, and sufficient capacity in motive power, this method has many points to commend it, where conditions of grade and road-bed permit it. Its principal disadvantage is the loss of time, for it would be, in most cases, impossible to maintain the regular schedule with the additional load on the motors. It would seem practicable to establish for certain days, a special slower schedule which could be maintained under the above conditions. The despatcher could issue the necessary orders to all trains that the special schedule had gone into effect, and inform them when it is annulled.

Still another method which solves the problem perfectly, as far as operating the road, and maintaining the schedule is concerned, is the coupling together of two or more motor cars in trains, controlled by a multiple unit system.

A number of interurban roads now have their cars equipped with the multiple unit system of control, and there is no doubt many more will be, for it forms the ideal train. The system

has only one objection if it can be so called—it is expensive; in first cost, because of the added controller equipment; in operating cost, because of increased power consumed, and in cost of maintaining the added equipment. When we consider that it provides a better, faster service for the public, it is hardly fair to call the above objections, as every improvement in service costs extra. The only question to the manager is, can he afford to so equip his cars? The financial condition of each road must settle it.

The increasing weight and power of interurban cars has rendered the old form of series-parallel controller inadequate to perform the work imposed upon it, which gives another potent reason for the adoption of multiple unit control, whether it is necessary to run the cars in trains or not. On some of the heaviest interurban cars, operating four 150 horse power motors, it becomes a necessity, for it provides a controller of a size and design which is capable of handling any amount of current the car may require. It removes a cumbersome controller from the platforms, and places it under the car where there is sufficient space for the necessary apparatus.

The number of stops also has a decided effect on the cost of operation when the train units increase. The cost of a local stop is in some cases greater than the fare paid.

Trailer Cars

Because of the fact that many railway managers are seriously considering the use of these cars, it is perhaps advisable to discuss them at greater length. In years gone by any old single truck car which happened to be in stock, perhaps an old horse car, or a motor car stripped of its motors, answered the purpose. It was coupled to the motor car by a light, inadequate form of coupler, and frequently, where grades were heavy, it was necessary to use a man on its front platform to operate the hand brake, as the motor car had only a hand brake of its own. This man in some cases operated the signal bell of the motor car when the conductor was on the trailer, repeating the latter's signals to the motorman. When traffic was so heavy as to require a second conductor for the trailer, then there was practically no saving in platform expense over two motor cars. The appearance of the larger types of motor

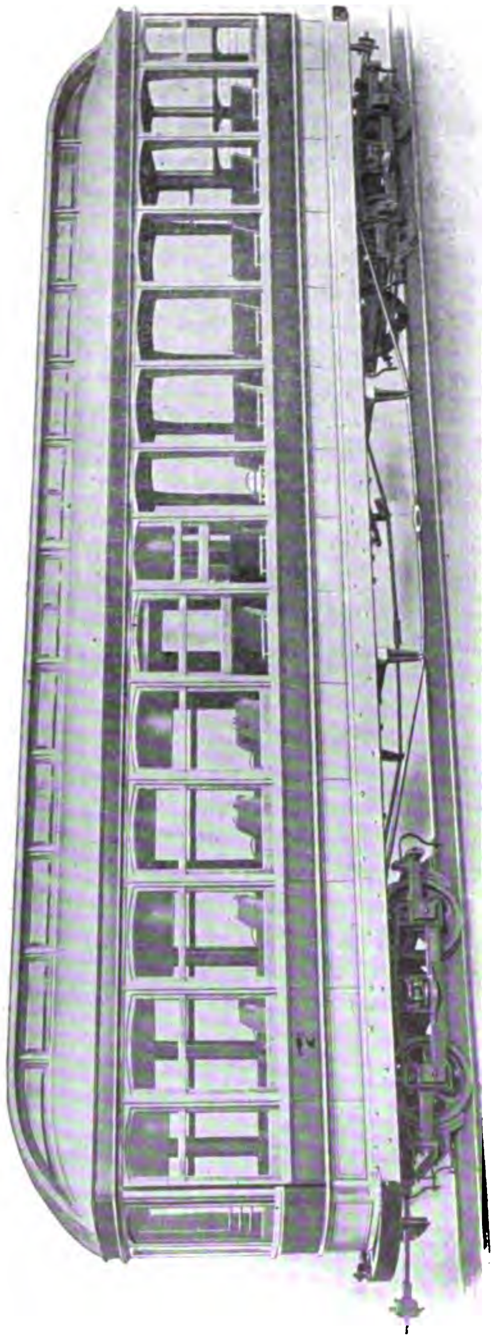


Fig. 68.—Trail Car Used in Cleveland, Ohio.

cars, with greatly increased seating capacity, was hailed with pleasure as a relief from the existing conditions, and the use of trailers was abandoned on many roads.

At present many roads in cities are using powerful four-motor cars for city as well as suburban service. They are from 34 to 42 feet in length, with a large seating capacity. If the road has not many heavy grades these cars are often overpowered, but in northern latitudes they need all their power during snowstorms, and in many cases they are the only cars which can run through the storm. This extra power could easily be utilized in good weather to haul a trailer, and in many cases it could be done with little, if any, loss in running time, and without overloading the motors. It is not the intention to advocate here the use of more than one trailer to a motor car in city service. The trailer should be especially built for the service. It may be of light weight, but strongly built, with double trucks, and quite as long as the motor car; equipped with air brakes or some other form of power brake matching those on the motor car, and coupled with them, the whole being operated by the motorman. Whether it should be possible for passengers to pass from car to car is a question to be determined by local conditions, but probably not. An operating condition is frequently noticed whereby there seems to be a preference among passengers to ride in the trailer, rather than in the motor car. This is especially noticeable in summer when a closed motor car is used with an open trailer. The loss of weight in the motor car reduces its tractive power, and sometimes renders it difficult to haul a heavily loaded trailer. There should be an extra conductor, and to prevent accidents, entrance and exit only at the rear end of the trailer. Under certain conditions, in city service in summer, it might be a cross seat open car with a guard rail on the inside, where track is double, and the train should always be run single ended, that is on a belt line or around a loop. Under ordinary conditions, it would not be good practice, at the end of a line, to run around a trailer on a switch, and couple to the other end for the return trip. With trucks placed near the ends of the car, and a modern automatic coupler, such a train should take all ordinary curves in a city, and could be run with reasonable safety to passengers at moderate speeds.

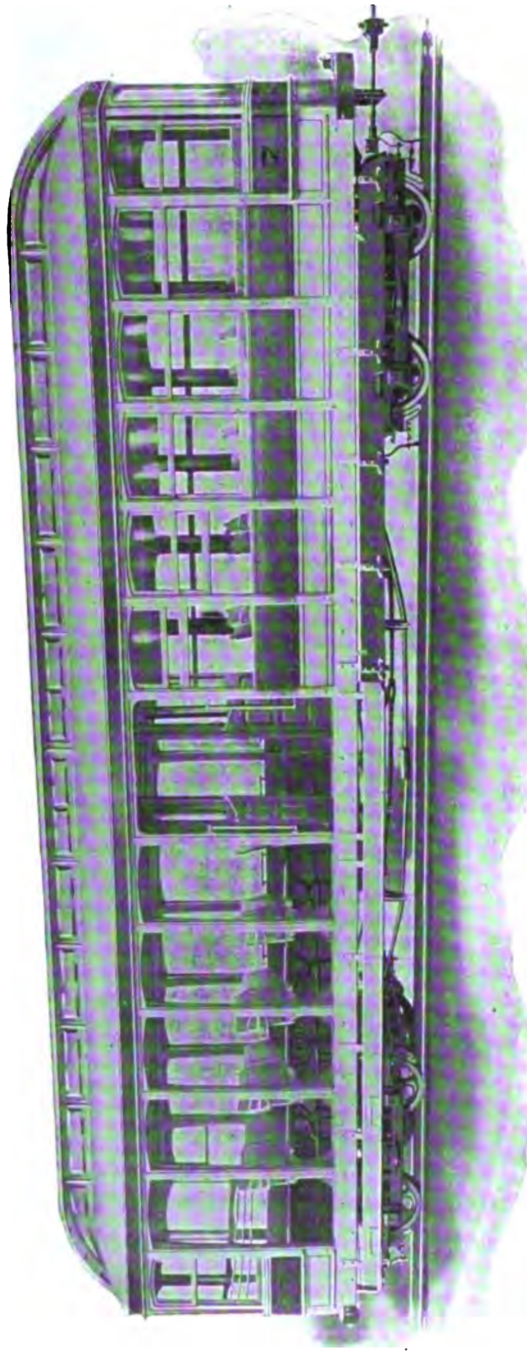


Fig. 69.—Trail Car Used in Cleveland, Ohio. Open Side.

The latest development in trailer cars for city service is to be seen in Cleveland, Ohio. These trailers are 35 feet 6 inches long over the end posts, and 45 feet over all. A novel feature is that one side is convertible and the other the closed type of construction. When closed one side has a longitudinal seat and the other side cross seats. When open the convertible side becomes an open car with a running board, and the longitudinal seat is swung round in sections matching the cross seats, and the car is an open car with all cross seats, but with the side toward the center of the double track closed. Figs. 68 and 69 show the two sides as an open car, and Fig. 70 shows the interior when the car is closed. This type provides a summer and winter trailer, which also gives a considerable degree

FIG. 70.—Trail Car Used in Cleveland, Ohio. Interior.

of safety for passengers by making it impossible to leave the car on the wrong side. Motor cars of the same type have recently been put in service.

The use of one or more trailers on an interurban road is a different proposition. Here again the trailer should be specially built, and while not necessarily as heavy as the motor car without motor equipment, it should be heavy enough to keep the rails, at speeds of 40 to 50 miles per hour.

The semi-convertible or the type shown in Fig. 71 might be used.

Trains consisting of a powerful motor car with two, or even three of these trailers, could handle a large number of passengers for a few hours, by putting into effect for the necessary

FIG. 71.—Semi-Convertible Trail Car Used by Syracuse Northern Traction Co.

time, a modified time schedule suited to their speed. On many roads it would even be possible to maintain the regular schedule of limited trains bound for distant points; for in nearly all cases of a rush on an interurban road, the crowd are bound for some pleasure resort, and a lower speed for their trains would not be a serious objection.

The use of Minneapolis-St. Paul gates on either motor car or trailer might be practicable on interurban runs, but in city service it is a debatable question. Their use in many cities would be practically out of the question, as in New York, for example. They probably prevent many accidents, which is their principal object, but the time taken to load and unload through the single entrance would often be prohibitive. Some of the advantages and disadvantages of the use of trailers which apply more particularly are as follows:

Advantages:

1. Saving in platform expense due to the necessity of only one motorman.
2. Trailers are lighter for same seating capacity and the saving in current over two motor cars, in a two-car train, may reach 50 per cent.
3. Trailers are much cheaper than motor cars.
4. Maintenance charges greatly reduced.
5. They afford a means for handling rush hour traffic without holding motor cars in the house.

Disadvantages:

1. A more or less reduction in speed.
2. The necessity of using more powerful motors than might otherwise be the case.
3. The probability of additional stops owing to the greater carrying capacity.

These objections do not seem serious, and under some conditions can mostly be overcome.

CHAPTER VII

TRAIN DESPATCHING AND SIGNALS

Train Despatching

The principal use of the telephone line, which now forms a part of the equipment of every modern interurban road, is to control the movement of the trains from a central point. It has been found, after numerous experiments, that the telegraphic train order system used for many years by all steam roads is difficult to improve upon. All attempts to simplify it have been attended by risk. Briefly the system is as follows: The despatcher, located at a central point, has before him the "train sheet," which is of suitable size for filing, and is ruled in cross section with the names of stations, or telegraph offices, on the vertical margin, and the train numbers on the horizontal. Every operator along the line telegraphs the despatcher the time every train leaves his station, with the train number. The despatcher enters the time in the proper space, under the train number, and opposite the name of the telegraph station. In this way he knows at all times between what stations every train is, and whether they are on schedule time.

On single track roads if a train loses a certain amount of time it is said to have lost its rights, and is then run by train orders, from the despatcher, his object being to avoid delaying the other trains, especially those running against it, and his orders are usually for the purpose of changing the meeting points for this train so that the others may not wait for it. The despatcher telegraphs his order to the operator next ahead of the train, who writes it out in triplicate blanks provided for the purpose, repeats the order back and receives the O. K. of the despatcher. The written orders are handed to the conductor of the train, who reads it aloud to the operator, and signs his name. He takes two copies to the train, keeps one and gives the other to the engineer, who in turn reads it aloud to the conductor. The engineer places it on file where he can see it and

the train proceeds. The operator then telegraphs the despatcher that the order is complete. Slight variations in the manner of reading and signing the orders are in use, but the above is the usual procedure. Sample forms follow.

X, Y, & Z RAILWAY.

CLEARANCE CARD.

............................190..

To Conductor and Motorman No..........

I have No Orders for your Train.

Time ....m ....Operator

Clearance Card Given to Train Crew by Station Agent.

Train Order.

X, Y, & Z RAILWAY.

Albion Shops..................190..

To Agent...............................

Order No. 6.

Train No. 16, Pass No. 13, at Siding No. 28.

Complete at..........m. Signed.......................

Train Order Transmitted Through Station Agent.

Train Order.

X, Y, & Z RAILWAY.

Hudson Station, Nov. 1, 1903.

To Motorman and Conductor:

Train No. 35, Motor No. 22, at Siding No 32.

Order No. 11.

Proceed against all other trains to Siding No. 35, and report.

Despatcher.

Complete 7:45 p. m. Signed.................Conductor.

Despatcher's Train Order Form to Conductor and Motorman Direct.

The despatcher, of course, keeps a copy of all orders he sends out in a book provided for the purpose, and each order is numbered consecutively.

It has often been said that train orders could not be given by telephone with the same accuracy and safety as by telegraph. This can only be true if the recipient fails to write the order, depending on his memory only. There is no doubt that such

methods have resulted in great carelessness and have caused many accidents in the past. It is now an accomplished fact that modern interurban roads have generally adopted the steam railroad system described above with very slight variations. Where the road has regular stations with agents on duty, almost the only variation is the use of the telephone instead of the telegraph. The agent receives the order, writes it out in triplicate and repeats it over the telephone as he has written it, to the despatcher and receives his O. K. The agent then hands copies to the motorman and conductor, who read them aloud, sign them and proceed with the train. They turn in these orders at the end of the run and they are compared with the copy in the despatcher's order book, to see if any mistakes have been made.

Many interurban roads have passing points where there are no stations or no agents. In these cases the telephone is in a booth to which the crew have keys, or a telephone is carried on the car and connected to the line at a pole where wires have been brought down for the purpose. The conductor or motorman then takes the place of the agent, and receives the order from the despatcher, writes it out in duplicate or triplicate and hands a copy to the other. The latter then reads it to the despatcher over the telephone and gets his O. K. In this way the despatcher has heard both men read the order as one of them has written it. It is doubtful if the telegraphic system, with operators, is any safer than this system.

Of great assistance to all employees is a printed folder of convenient size for the pocket, containing a complete time table giving the schedule of every train with its number (odd numbers for trains in one direction and even numbers in the opposite) and showing all meeting points with other trains in the regular schedule. All rules pertaining to the running of trains, orders, signals, etc., should be contained in it. It is the practice to issue these on all steam roads, and it teaches the employees how the road is operated and the part they play in it. On many interurban roads most of the sidings, or meeting points, have no one on duty. The conductor is then supposed to call the despatcher and ask for orders. This is usually done at every passing point, and sometimes at other designated sidings which may not be scheduled passing points. This fre-

quency of communicating with the despatcher depends entirely on local operating conditions.

In a street railway system the despatcher's duties are still important, though his title may be Starter, or Foreman of a car house. He is supposed to handle the train crews and regulate the headway so as to have the proper number of cars on the different runs, at all hours of the day.

A good practice is to equip each car with a small sign, easily exchanged, giving the number of the run. On the interurban lines, this becomes the train number, and regular patrons learn to know the train by its number, which is a convenience to many, as it associates with it in the mind the schedule of the train throughout its run.

Block Signals

Many roads which are operated without any train despatching system depend entirely on the signal block, and there are conditions existing which show it to be a very satisfactory method of operating. Especially is this true of a double track road. Two general classes of block signals are in use—those operated manually, and the automatic system. The manually operated system has the advantage of continual inspection by the operators, and the responsibility for the proper signaling of the system rests on them. In the case of the automatic signal systems this responsibility is removed from the operators, and when the system fails the road is operated under a greater hazard than if no signals are used. The former are most widely used probably because they were first in the market and are cheap. In their simplest form, consisting of incandescent lamps in boxes on a pole at each siding with a pair of switches, any road can manufacture its own at little expense. Other manual systems have lamps and switches, and sometimes a telephone enclosed in a neat iron box under lock and key, but so arranged that the crew can operate the switches with a special handle carried by them, thus rendering it impossible for outsiders to interfere with the system.

All manual systems require that the car shall stop at the end of every block in order to operate the system, and determine whether the block ahead is clear, and if so, to set it against all cars running opposite and approaching the other end. Also

to clear the block in the rear, if more than one car is not allowed in a block.

Fig. 72 shows the manually operated signal block in its simplest form. It requires only one signal wire along the line, in which are placed groups of lamps, five in series, with two at one point and three at the next. The lighting of these lamps shows that a block is closed or occupied. Their extinguishing shows a block is clear. Thus a car approaching the point A finds the block A B closed, but if the car were at B the block B C would be found clear.

The various automatic block systems for electric roads cannot be said to have reached their highest state of perfection. The problem is much more difficult than that encountered in the automatic electric signals used on steam roads, for the reason

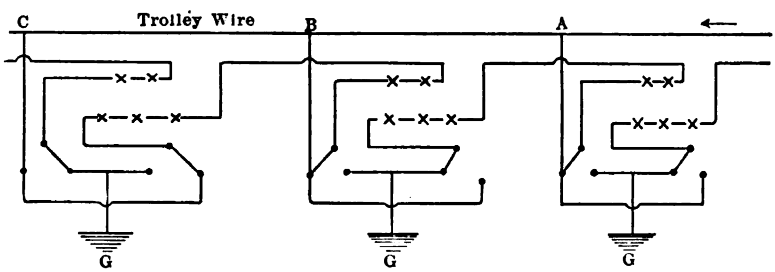


FIG. 72.—Manually Operated Signal Block.

that in the latter the service rails can be cut up into sections, insulated from each other, and used for carrying the signal current. For electric roads, systems have been devised in which one service rail is given up and signals are operated by the car wheels, the signal current being either direct or alternating current. On an interurban road this leaves only one rail of a track to return the current from the car motors and necessitates the use of negative copper feeders. On an elevated road the disadvantage is not so great if the steel of the structure is also used for a return. Other systems are those which do not use either rail, and are probably destined to come into more extensive use. These require the use of signal wires on the poles carrying a current taken from the power supply which operates electro-magnetic semaphores as well as lamps. These systems are actuated by a form of mechanical switch attached

to the trolley wire and thrown by the trolley wheel. They are comparatively simple, and if the mechanical and electrical details are well worked out so that the cost of maintenance is reduced to a reasonable figure, they should give satisfaction.

A system on the above principle should work as follows: Several hundred feet each side of the turnout there should be a signal, one for each block. Each signal should consist of two semaphore arms, a red one above a green as well as a red above a green light. As the car reaches the siding, if the block ahead is clear, both semaphore arms are down. When the trolley wheel throws the switch overhead, the green or lower arm takes the horizontal position. This arm should be electrically interlocked with the red or upper arm of the next signal ahead at the other end of the block, thus protecting the block from any car entering the opposite end. The car then enters the block and the trolley wheel strikes a second switch, throwing up the red or upper arm at that end and throwing up the green arm at the other end with which it is interlocked. In this way both ends of the block are protected and as the car passes out at the other end the switch clears all signals in the rear and sets those in the next block if that shows clear.

These systems are those known as "normal safety," meaning that when no cars are in the block the signals are clear. "Normal danger" systems are preferred by some, but it is doubtful if any have yet been worked out for electric roads operated without the use of the rails. In this case all signals stand at danger, or all blocks are closed, when no cars are in operation. The approach of a car clears the signal ahead if no other car is in the block, and the signal protects the block again as the car passes in. It is considered very important by some that any break or disarrangement of the signals causing a failure to work properly should result in these signals failing at danger. The construction should be such that no signal could fall at clear even if all current went off the line. There is a difference of opinion on this point, however, as some roads object to the tying up of the system because of the failure of one signal. It is a fact though that most steam road signals are constructed to fail at danger.

A very important point upon which there is a wide difference of opinion is that of allowing a number of cars to follow

one another through a block. On general principles railroad men will admit that but one car at a time is the safest and best plan. At the same time there are roads which simply could not operate successfully in that manner. The whole question depends on the headway of the cars and the length of

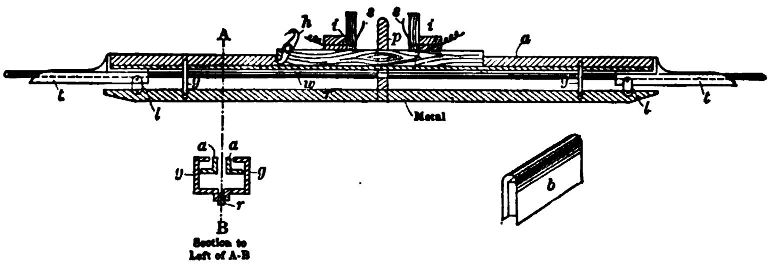


FIG. 73.—Contact Device of the Jackson Automatic Block Signal.

the blocks. If the headway is short and but one car is allowed in a block the only remedy is to shorten the blocks and passing points, and as both become shorter it would soon be cheaper to double track. On the other hand, with long blocks, and sidings of sufficient length, it is possible to pass three or four cars

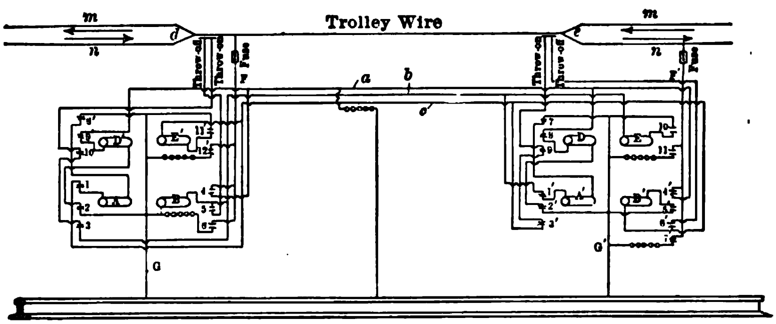


FIG. 74.—Wiring for Jackson Automatic Block Signal.

in opposite directions and run them with reasonable safety from rear end collisions, if sufficient care is exercised by the crews.

The greatest care should be always used in maintaining block signals whether hand operated, or automatic, in order to keep the proportion of failures at the lowest possible point. Block signals should never be adopted without instructing the men

in the most positive manner to obey them under all circumstances until otherwise ordered by one in authority. Nothing

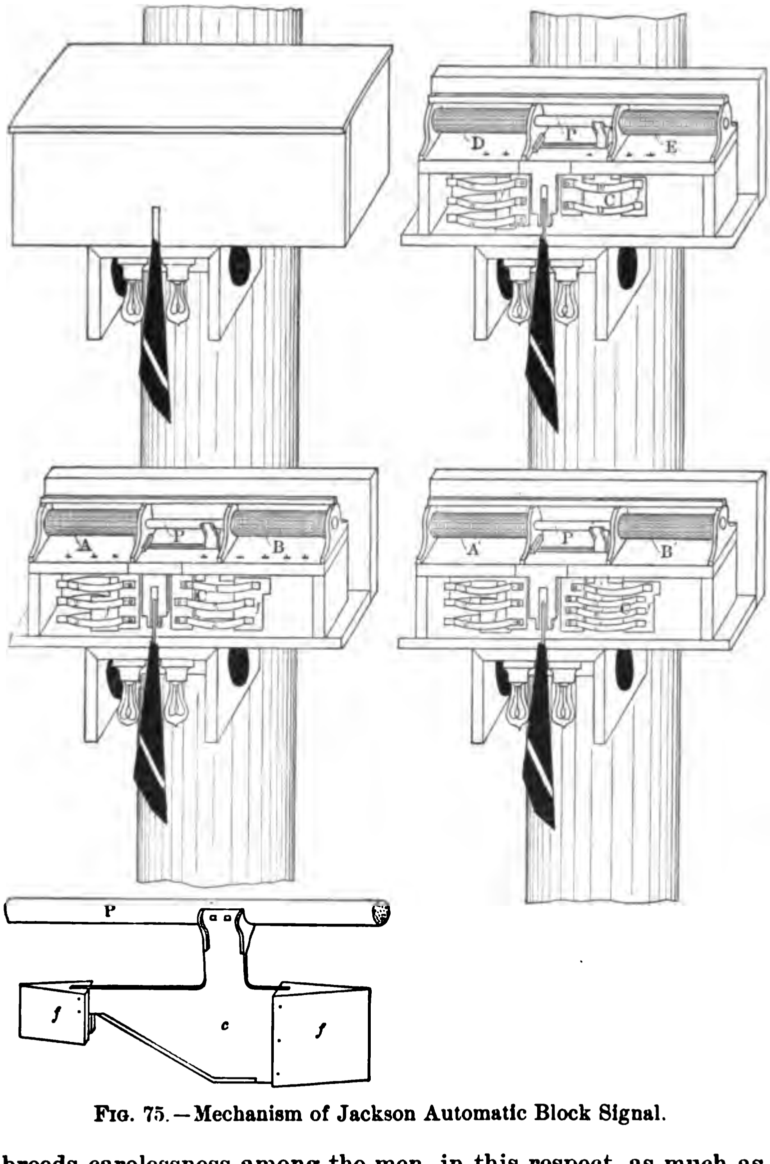


Fig. 75.—Mechanism of Jackson Automatic Block Signal.

breeds carelessness among the men, in this respect, as much as a few failures of the signals to work properly. When such a

condition arises it is far better and safer to have no signals.

Figs. 73, 74 and 75 show the mechanism, the contact device worked by the trolley wheel, and the wiring plan of the W. S. Jackson automatic block signal system which is in successful operation.

CHAPTER VIII

ROLLING STOCK

THE SELECTION OF CARS

THIS is such a broad question, and one governed by so many different conditions, in various localities, that to give a general idea of modern practice, it is necessary to assume what may be called average conditions, i. e., a city of moderate size, not exceeding 40,000 population, in which there is operated a railroad system consisting of the usual city lines; a few short suburban or light interurban lines; and a heavy interurban road, of high speed, and considerable length. But there are certain physical conditions inherent in a property, which, from an engineering standpoint, limit the selection of the equipment to be operated. The length of the car is frequently determined by the radius of curves and width of streets; the width of the car by track centers, and sometimes by center pole construction. The height is usually limited by overhead bridges and by the grade approach to them. The increased power consumption of large cars is reflected in the increased power station output, and in the reduced voltage for acceleration. Every railway manager will not agree with the ideas on a proper equipment of rolling stock expressed here, but it is proposed to give what might be selected by a majority of managers, operating roads under somewhat similar conditions, as expressed by them during recent times.

The question should be considered under four heads, viz.—Length, seating capacity and arrangement, weight and motive power. These four points should also be considered separately, as regards the three classes of service, urban, suburban or light interurban, and heavy interurban. A most important point is whether a double equipment for summer and winter is advisable. In cities of the type assumed here, it seems to be the opinion of many, that the purely city service can be better and more economically conducted by the single truck car 20 or 21

feet long over end posts. For winter the ordinary closed type with longitudinal seats, and roomy platforms, with vestibules in the colder climates, as shown in Fig. 76. Single trucks of a modern type, are much better than the older forms, and effectually prevent much of the oscillating motion. For summer use, in the same service, single.truck, cross seat, open cars with footboards on each side, are generally acknowledged to be the best, if traffic is not too dense. This type is seen in Fig. 77. These cars have a great seating capacity for their weight and are very economical in power consumption. Their motive

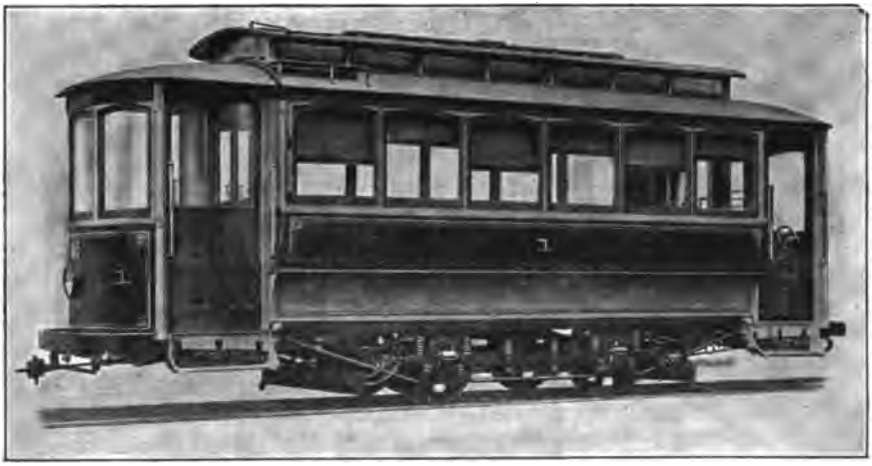


FIG. 76.—Closed Type Single Truck Car.

power should consist of two 40 horse power motors but it is not advised that they should be permitted to haul trailers.

In a city of this type the greater part of the rush hour traffic is usually suburban, and the single truck cars should be able to handle the purely city traffic without many extras. By suburban or light interurban lines are meant those which extend a few miles beyond the limits of the city, and on one, or more, may be located a park or pleasure resort. The cars of these lines, in addition to the suburban traffic, help the city traffic also, to a large extent. They should be capable of maintaining a maximum speed of about 30 miles per hour, and, as far as possible, the city cars should not run over their route in the city, at least not in a manner to interfere with their

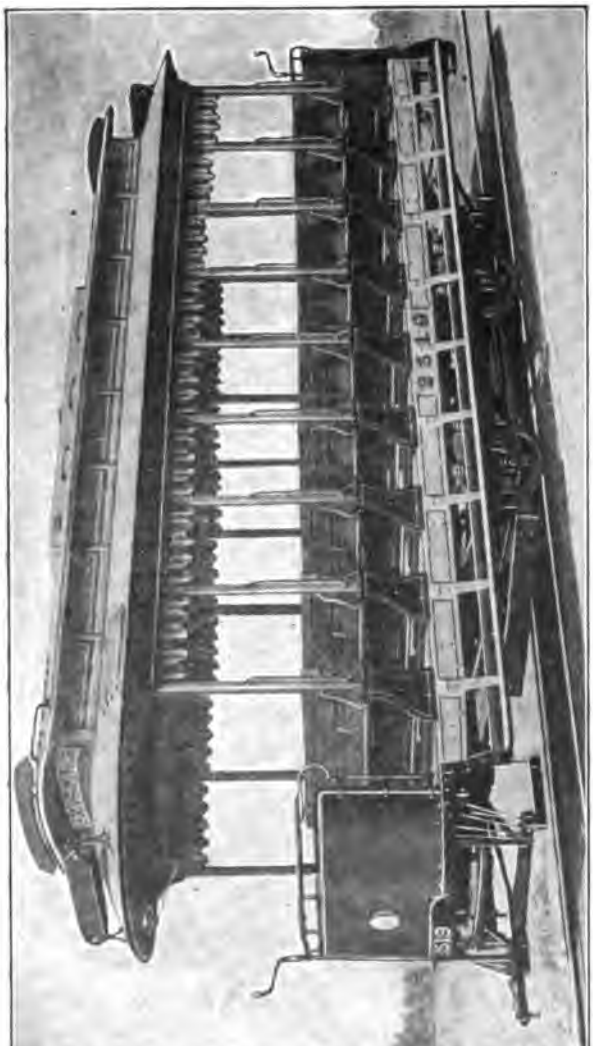


Fig. 77.—Open Type Single Truck Car.

faster schedule. The semi-convertible type, with double trucks, and four motors of about 40 or 50 horse power each, able to haul at least one trailer of equal size, may be used. The motor cars should have cross seats with center aisle and vestibules. Under some conditions it is best that they be single ended, provision being made for a Y or loop in the track at the outer end, and a loop in the city. There is little doubt that in this class of service the public greatly prefer the cross seat type. Cars of this type, with front half cross seated, and rear half longitudinal, have been popular. Invariably the cross seats are filled first, and in the rear there is good standing room. In length the motor car should not be less than 40 feet over all, and the trailer preferably of the same length. The latter, instead of being semi-convertible, might be a double truck open car with cross seats and foot boards. But it should be borne in mind in trailer construction, that they should be built as light as safety permits, for the reason that every additional ton of dead weight is a loss. As the traction coefficient of the motor car is approximated depreciation increases, as well as the cost of power. As the traffic on these lines will be much heavier in summer, than in winter, due to the large number of people who ride for pleasure, the open car would be the most popular. Fig. 77 shows a type of open car widely used as a motor car in summer for both city and suburban service. As a trailer it answers the purpose admirably. This provides a motor car which runs the year round, with sufficient power to overcome snowstorms, and a form of trailer to be used during the heaviest traffic in summer. The name, semi-convertible, conveys little meaning, for the car in appearance is a closed car, in which the windows can be quickly removed, either by lifting them into roof pockets, or dropping them into the side frame, thus clearing the whole window space. It has been claimed, that by reason of their design, they are not strong, and are difficult to heat. It is unlikely that they can be built as strong as a standard closed car, but the addition of an outside storm sash in winter would obviate the heating objection. For the service described above, and the speed mentioned, there is no doubt that they can be built sufficiently strong.

The seating capacity of the motor car will be about 44 and of the open trailer about 70.

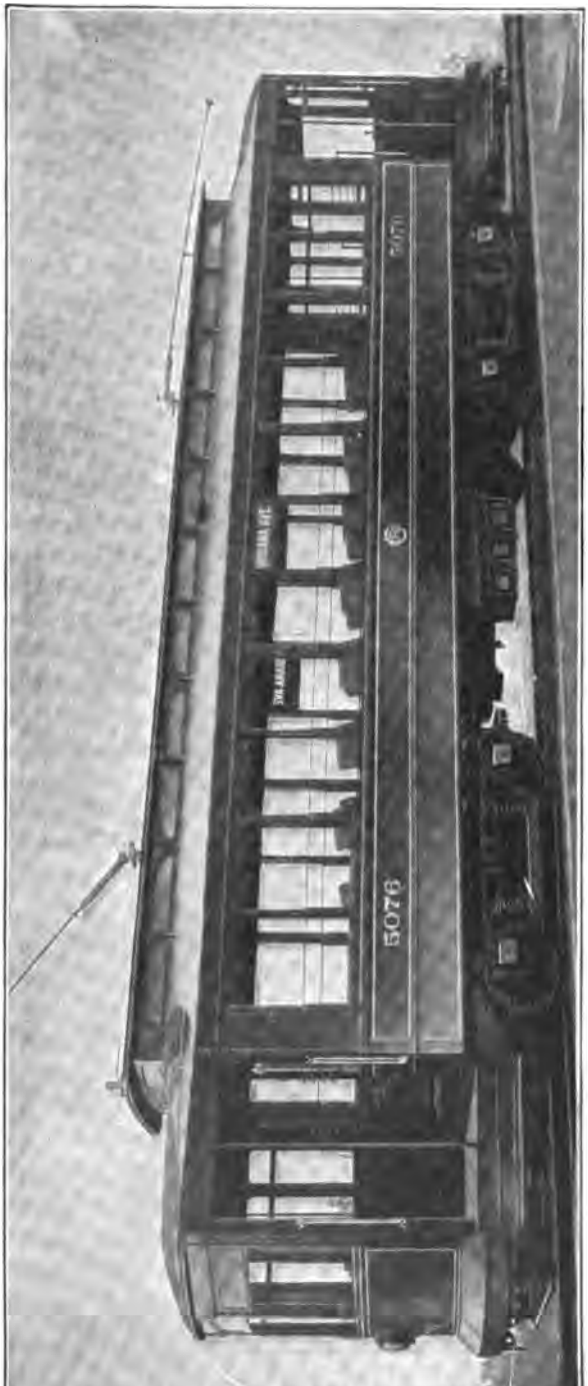


FIG. 78.—Semi-Convertible Car for City and Suburban Service.

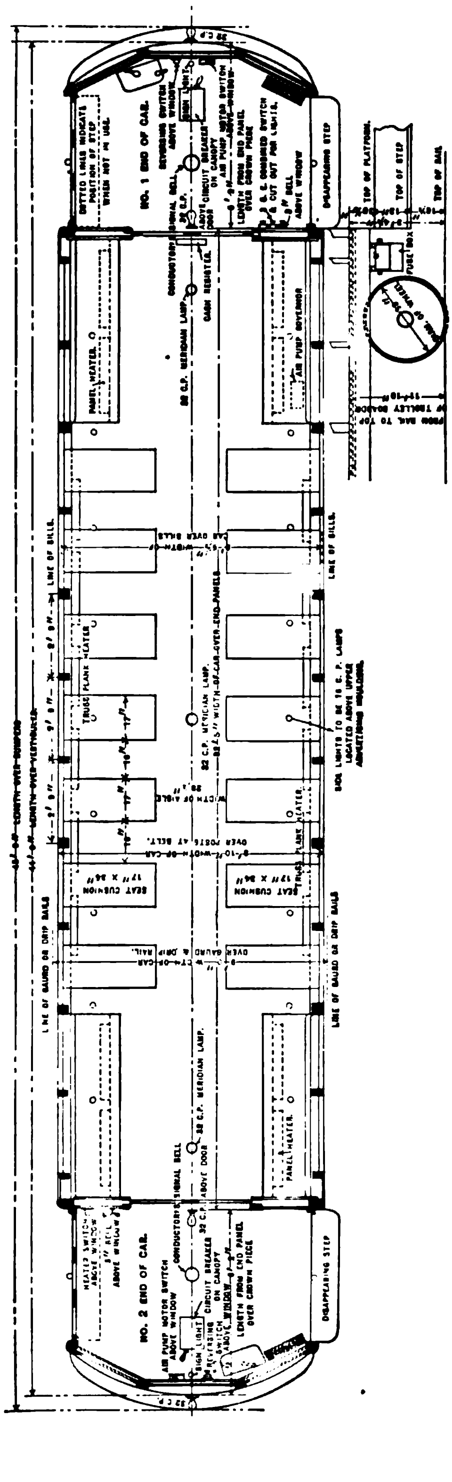


FIG. 79.—Plan of Semi-Convertible Car for City and Suburban Service.

The weight of the motor car complete without load is 60,000 pounds, equipped with four 40 horse power motors. Weight of open trailer about 30,000 pounds.

Many prefer a double ended motor car where passengers can enter and leave by both platforms, and where traffic at times is very congested, this is a relief, and a time-saver. Fig. 78 shows a recent design of semi-convertible car for city and suburban service used in Chicago. In such a case the seating plan of the car shown in Fig. 79 suits average conditions very well. The long side seats at the ends afford considerable standing room, the platforms are long, and the seating capacity

FIG. 80.—Steel Car for City Service.

44, and the length of the car, 33 feet body, and 44 or 45 feet over vestibules, is not too long for the service.

The use of a dividing rail on a wide platform, leaving the exit clear for passengers, has been found to be an advantage in the time required for loading and unloading, especially where smoking is allowed on the rear platform.

Fig. 80 shows a steel car for city service.

The following table shows some dimensions of cars used in city and suburban service in the cities of Brooklyn, Buffalo, Detroit, Jersey City, Kansas City, Nashville, Philadelphia, Long Island City, St. Louis and Toledo. As these cars are distributed over a considerable portion of the country they represent current practice fairly well.

TABLE XXIV

LATEST STANDARDS OF ELECTRIC CARS IN AMERICAN CITIES

PLACE.	Car Length.		Platform Length	Width Maximum.	Seats.		No. Long.	Total.	Length Cross Seats.	Width Aisle.
	Over Bumpers.	Over Corners			Car Op. 1 or 2 Dir'ns.	No. Cross.				
Brooklyn	41′	......	......	......	2	40	8	48	34″	24″
Buffalo	36′ 5″	26′	4′ 8½″	8′	2	0	34	34	0	0
Chicago	45′ 9″	32′ 5″	6′ 2″	9′	2	28	16	44	35″	28″
Detroit	41′	29′	5′ and 6′ ½″	8′ 1″ (over sills)	1	24	19	43	..	..
Jersey City, Newark, etc. ..	42′ 8″	30′ 8″	6′ (incl'd's bumpers)	7′ 11½″	2	35	8	43	..	..
Kansas City...	43′ 8″	30′ 7″	5′ 9″	8′ 6″	2	36	8	44	34″	..
Nashville	42′	30′ 6″	5′	7′ 11½″	2	28	16	44	34″	23½″
Philadelphia ..	37′ (over crown pieces)	28′	4′ 6″	8′ 3″ (over posts)	2	32	8	40	..	..
Queens Boro', New York City	40′ 8″ (over vestibules)	30′ 8″	5′	8′ 6″	2	28	16	44	37″	24″
St. Louis	46′ (approx)	33′ 4⅝″	3′ and 7′	9′ 1″	1	40	12	52	32″	32″
Toledo	41′ 4½″	30′ 8″	4′ 8½″ and 6′	8′ 2″	1	28	16	44	34″	26″

The following may be considered average figures:

	Over all.	Over end posts.
Av. Car lengths	41′-6″	30′-0″
Max. " "	46′-0″	33′-4″
Min " "	36′-5″	26′-0″
Av. width	over side sills,	8′-4″
Av. seating capacity,	43.6	

The average length of a cross seat is 34 inches and width of aisle 24 inches. This gives a narrow aisle, and seats rather short, but these are governed by the width, 8 feet 4 inches, which should be 9 feet, or a little more. Unfortunately, narrow track centers in the double track in use, in most of the cities mentioned, prohibit any increase in width of the car. Fig. 81 gives the track centers, gauge and width of cars used in different cities.

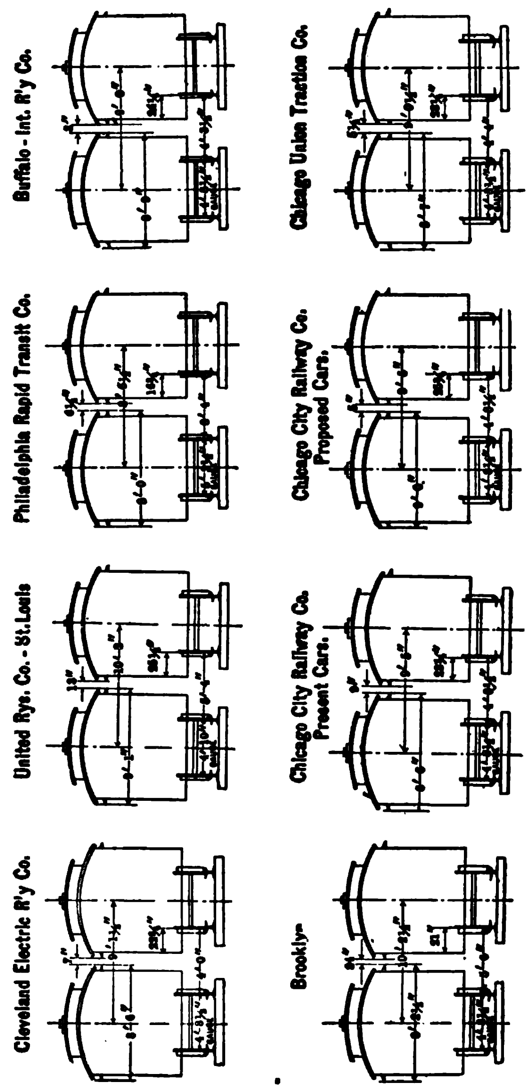


FIG. 81.—Truck Centers, Gauge and Width of Cars Used in Different Cities.

TABLE XXV.—PRINCIPAL DIMENSIONS OF STANDARD CARS USED IN FIFTEEN LARGE CITIES.

Number.	City and Name of Company	Closed and Semi-Convertible Cars. Single, Double or Maximum Traction Trucks.	Length of Body.	Length Over All.	Length of Platforms.	Width of Car Body at Sills.	Width of Car Body at Belt Rail.	Height Side Top Rail rom Floor.	Height of Step from Rail.	Height from Step to Platform.	H'ght Riser from Platf'm to Car Floor.
1	Baltimore—United Rys. and Electric Co.	M. T.	28 ft	38 ft.	5 ft.	7 ft. 6 in	7 ft. 10 in.	6 ft. ⅛ in	15 in.	18½ in.	7¾ in.
2	Boston Elevated Ry. Co.	M. T. & double	25 ft.	33 ft. 3 in.	4 ft.	6 ft. 8 in.	7 ft. 6 in.	5 ft. 7 in.	16 in.	18 in.	7 in.
3	Buffalo Railway Co.	Double	30 ft. 6 in	40 ft. 8 in	4 ft. 3 in.	7 ft. 8½ in.	8 ft. 2 in	6 ft.	16 in.	18¼ in.	8 in.
4	Chicago City Ry. Co.	Double	34 ft.	48 ft. 2 in.	6 ft. 5 in.	8 ft. 8 in.	8 ft. 8 in.	5 ft. 8 in	16 in.	12 in.	10 in.
5	Cleveland Electric Ry. Co.	Double	30 ft.	43 ft.	5 ft. & 6 ft.	6 ft. 6 in.	8 ft. 2 in.	6 ft ⅛ in.	17 in	2 steps 17 & 18 in.	8 in.
6	Denver City Tram Co.	Double	36 ft 4 in.	41 ft. 6 in.	Side ent. 5 ft. 2 in.	7 ft. 8½ in.	8 ft 2 in.	6 ft.	14½ in	2 steps 11 & 12 in.	3½ in.
7	Detroit—United Ry. Co.	Double	28 ft. 2 in.	41 ft.	6 f. 6 in. 5 f. 6 in	8 ft. 1 in.	8 ft. 1 in	......	14⅝ in.	18½ in.	10 in.
8	Indianapolis Traction & Terminal Co	Double	32 ft.	45 ft.	6 ft.	8 ft. 4 in.	8 ft. 7 in	6 ft.	17 in	12 in.	9 in.
9	Milwaukee Electric Railway & Light Co.	Double	29 ft.	41 ft.	5 ft.	8 ft. 1 in.	8 ft. 5 in.	.....	......	....	....
10	Minneapolis-St. Paul—Twin City R. Tran. Co.	Double	33 ft. 1 in.	45 ft. 2½ in.	5 ft. 3 in	8 ft. 5⅞ in	8 ft. 5⅞ in.	5 ft. 10¾ in.	16 in	2 steps 18 in	5 in.
11	Philadelphia Rapid Transit Co.	Double	28 ft.	38 ft.	4 ft. 6 in.	7 ft. 9½ in.	8 ft. 3 in.	5 ft 10 in.	15⅞ in	18 in	8 in.
12	Pittsburg Rys. Co	Single	19 ft 11 in.	30 ft.	4 ft. 5 in.	6 ft. 7½ in.	7 ft. 2 in.	5 ft. 9½ in.	16 in.	12 in	8 in
		Double	30 ft.	42 ft. 8 in.	5 ft. 6 in.	8 ft. 6 in.	8 ft. 6 in.	5 ft. 10 in.	15 in	18 in	10 in.
13	San Francisco—United Railroads	Double	California type 38 ft.	39 ft 6 in	Two side entrances, 2 ft. 8 in.	8 ft. 2 in	8 ft. 2 in	5 ft. 7¾ in.	14 in.	2 steps of 12½ in.	None
14	St Louis Transit Co	Double	33 ft. 4¾ in.	44 ft. 8 in.	3 f. 6¾ in. & 7 f.	9 ft. 1 in.	9 ft.	6 ft.	14¾ in.	18 in	18 in

Number.	Closed and Semi-Convertible Cars				Open Cars.									
	Cross or Side Seats.	Seating Capacity.	W'ght Complete Without Passengers.	Kind of Brakes.	Single, Double or Maximum Traction Trucks.	Length Over All.	Width Over All.	Height Side Top Rail from Floor.	Height Running Board from Rail.	Height from Running Board to Floor.	Number of Benches.	Seating Capacity	W'ght Complete Without Passengers.	Kind of Brakes.
1	Side	46	ℓ 21,760	Hand	M. T.	38 ft. 9 in.	7 ft. 10 in.	6 ft. 1 in.	18¼ in.	16 in.	12	60	ℓ 23,100	Hand
2	Side	34	24,660	Hand	{ Single, M. T. and double }	29 ft. 4 in. 34 ft. 2 in.	7 ft. 6 in. 7 ft 6 in	5 ft. 5 in. 5 ft. 5 in	19¼ in 19¼ in.	15½ in. 16 in.	9 12	45 60	15,080 22,073	Hand } Hand }
3	Side	40	40,180	Straight Air	Double	42 ft 11 in.	8 ft. 9½ in.	5 ft. 7 in.	§12¾ in	§12 in.	14	84	34,924	Air & hand
4	Cross	52	48,000	Air	*	*	*	*	*	*	*	*	*	*
5	Side	34	28,000	Hand	Double	43 ft.	8 ft. 2 in.	6 ft. 1 in.	2 steps 18⅝ in.	12 in.	14	84	40,000	Hand
6	* Cross	48	34,000	Straight Air	*	*	*	*	*	*	*	*	*	*
7	Side & cross	43	......	Storage Air	*	*	*	*	*	*	*	*	*	*
8	Side & cross	52	32,000	Air	† Single	†34 ft. 5 in	†7 ft. 10 in	†5 ft 8 in.	† 18 in.	†16 in	†12	†60	† 18,000	† Hand
9	Cross	44	......	Hand	*	*	*	*	*	*	*	*	*	*
10	Side and 14 cross	52	48,000	Straight Air	M. T.	‡41 ft. 6¾ in	‡8 ft. 8¼ in	‡5 ft. 7½ in	....	....	‡26	‡52	‡ 26,500	‡ Hand
11	Cross	40	32,000	Straight Air	*	*	*	*	*	*	*	*	*	*
12	Side Side	30 50	ℓ 17,100 ℓ 32,600	.... Magnetic	Single Double	24 ft. 3 in 34 ft 2 in.	7 ft. 10 in 7 ft. 10 in.	....	17½ in.	16 in.	11 11	55 ..	.... } .... }	Magnetic
13	{ Cross outside Side inside }	44	33,500	Straight Air wheel & track }	*	*	*	*	*	*	*	*	*	*
14	Cross	50	40,000	Storage Air	*	*	*	*	*	*	*	*	*	*

* Same cars summer and winter. † The long closed semi-convertible car is also used in summer. ‡ Also uses semi-convertible car in summer.
§ Two 12 in. steps. ℓ Weight without motors.

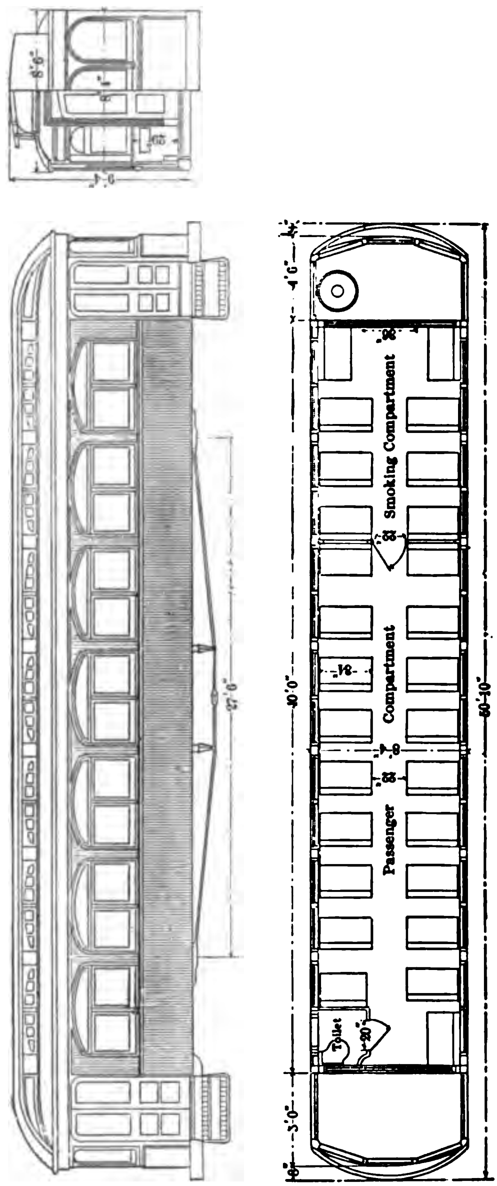


FIG. 82.—Side Elevation of Modern Interurban Motor Car.

The type of car best suited to an interurban service depends entirely upon various conditions; the road-bed, whether laid on private right of way, or on the highways, or both, and on the speed schedule deemed necessary. On the latter depend the weight and power of the car. Many interurban roads are running on the highways where the maximum speed seldom reaches 40 miles per hour, and then only on favorable stretches. Some of these roads have considerable length, and most of them use the type of suburban car described above, with slight modifications. But the modern types of interurban roads operate over a private right of way, except in the terminal cities, and are probably developed in the highest degree in the states of Ohio and Indiana. This type of interurban road uses the modern motor car, and the accommodations furnished the passengers are equal to those supplied by the steam roads. Fig. 82 gives a plan and side elevation of such a car, many of which have been built during the last two or three years. The seating plan is similar to a steam road coach, and in the larger number of these cars is a smoking, or baggage compartment. The total seating capaciay is 54, with a length over buffers of 50 feet 10 inches. The car body weighs 40,000 pounds, and the trucks and equipment about 30,000 pounds more, making 70,000 pounds total weight without load. These cars are usually mounted on steel trucks of the M. C. B. type, with swing bolsters and equalizers, or some modification of it, and their wheels are usually 36 inches diameter. The motive power generally consists of four 75 or 100 horse power motors, and they are capable of a maximum speed on the level of from 50 to 60 miles per hour.

The table on page 148 gives weights, dimensions and other data of some of the principal high speed heavy interurban cars in the West. The time is that of the limited service in which these cars are used.

Figs. 83 and 84 show types of these cars.

As an example of the heaviest type of steel motor cars to be used in this country the following data concerning those of the New York Central and Hudson River Railroad are given (Figs. 85 and 86).

The interior finish is similar to that of the New York Central standard coach, as the steel is painted mahogany color.

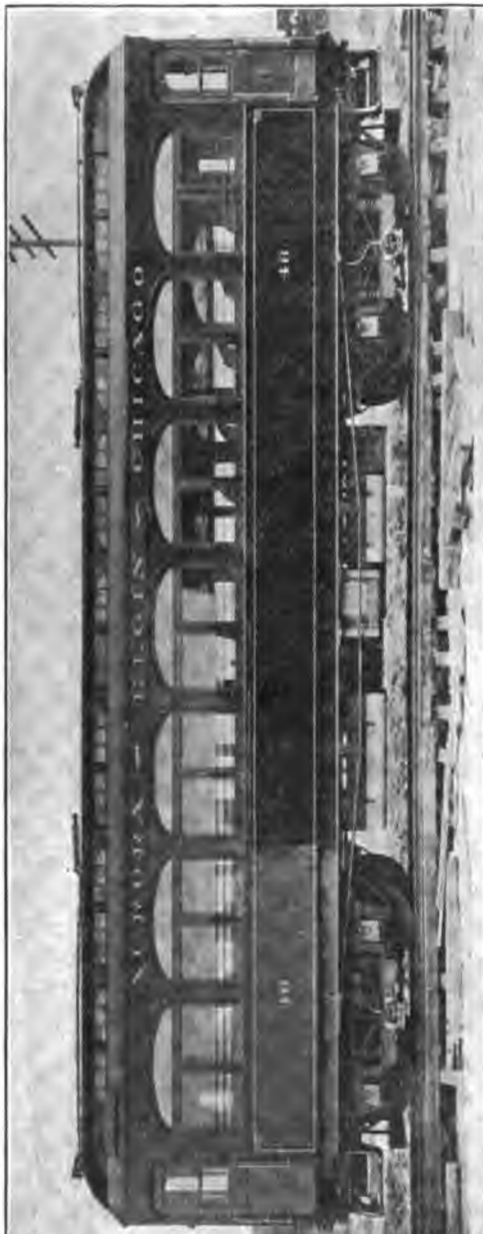


Fig. 88.—Type of Interurban Car.

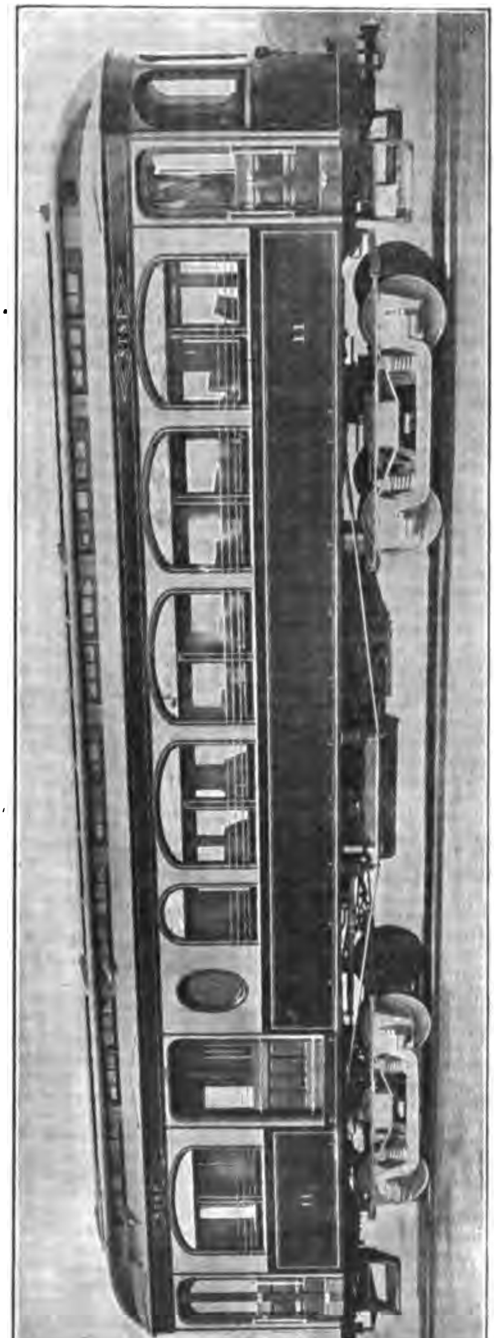


Fig. 84.—Type of Interurban Car.

TABLE XXVI

INTERURBAN CAR DATA

NAME.	From To	Distance	Time. Hrs.	Time. Min.	Time on City Track.	Stops.	Seating Capacity.	Length of Car.	Number and Size Motor.	Size of Wheels.	Kind of Wheel.	Flange Dimensions.	Weight of Car.
			Hrs.	Min.	Min			Feet.				In.	Tons
Lake Shore Electric Ry..........	Cleveland to Toledo	118	4	45	60	13	42	50	4- 75	34½	Steel Tire	1	34
Lake Shore Electric Ry	Cleveland to Sandusky...........	60	2	30	40	6	42	50	4- 75	34½	Steel Tire	1	34
Western Ohio & Dayton & Troy	Dayton to Lima ..	80	2	37	35	5	46	51	4- 75	37	Steel Tire	1⅛	35
Dayton & Western & Ind. & Eastern	Dayton to Indianapolis...........	108	4	15	55	8	26	45	4- 50	33	Steel Tire	⅞	32
Indianapolis & North Western..	Indianapolis to Lafayette	69	2	30	35	5	66	62	4- 75	33	Steel Tire	⅞	42
Indianapolis & North Western..	Indianapolis to Crawfordsville..	52	1	50	30	3	66	62	4- 75	33	Steel Tire	⅞	42
Indiana Union Tr. Co.	Indianapolis to Logansport	81	3		30	15	48	56	4- 75	37¼	Steel Tire	⅞	36
Indiana Union Tr. Co.	Indianapolis to Muncie	57	2	5	35	10	48	56	4- 75	37¼	Steel Tire	⅞	36
Columbus, Newark & Zanesville	Columbus to Zanesville	65	2	30	30	1	24	51	4-150	..	....	...	50
Detroit, Ypsilanti, Ann Arbor & Jackson	Detroit to Jackson	76	2	55	35	4	56	52	4- 75	36	Cast Chill.	11/16	32
Jackson & Battle Creek...........	Jackson to Battle Creek	46	1	30	25	3	64	60	4-125	28	Steel Tire	...	44
Grand Rapids, Holland & Chicago	Grand Rapids to Holland.........	34	1	15	30	7	52	49	4- 50	33	Cast	⅞	30

The seat frames are steel, and they are covered with fireproof rattan (Fig. 87). Baggage racks are carried continuously from end to end of the car on each side, and the rack brackets and all fittings are of statuary bronze. The car wiring is all located in loricated conduit.

As these cars must be coupled up behind steam locomotives for part of their run during the period of initial operation, the lighting and heating arrangements have to be in duplicate. The electric lighting is very complete, and includes single lamps over each seat, six groups of center lamps, and lamps in each saloon and at each end, making altogether fifty lamps in the car. The electric heaters are placed under each seat, except the two middle seats of each side. For operating as part of a steam train, the cars will be fitted with Pintsch gas lamps and steam heat.

The motors are rated at 200 horse power each and two motors will be used for each car, both motors being mounted on the

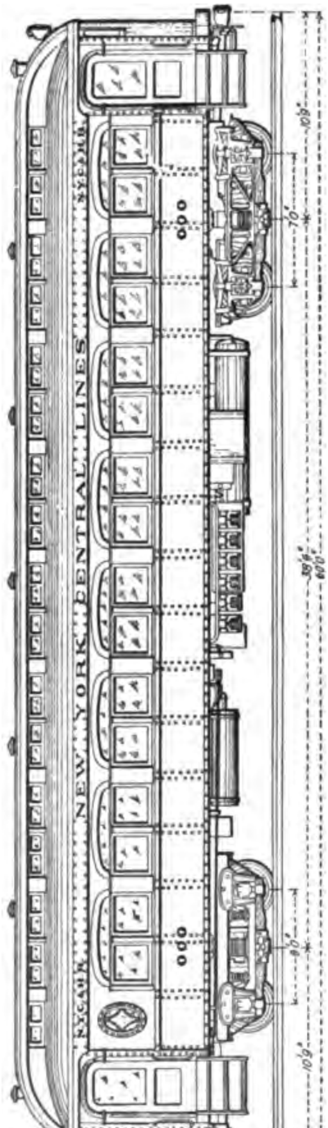


Fig. 85.—Side View of All-Steel Motor Car.

same truck. They will be operated at 650 volts, although it would be possible to run them at 750 volts. The motors will be geared 49:26, or 1:885.

The motor trucks are of all-steel construction, with axles 7 inches in diameter at center and 7⅞ inches in diameter at the wheel fit, and with journals 5½ inches x 10 inches. The trailer trucks will have axles 6½ inches in diameter at the wheel fit, and with 5-inch x 9-inch journals. Thirty-six-inch wheels will

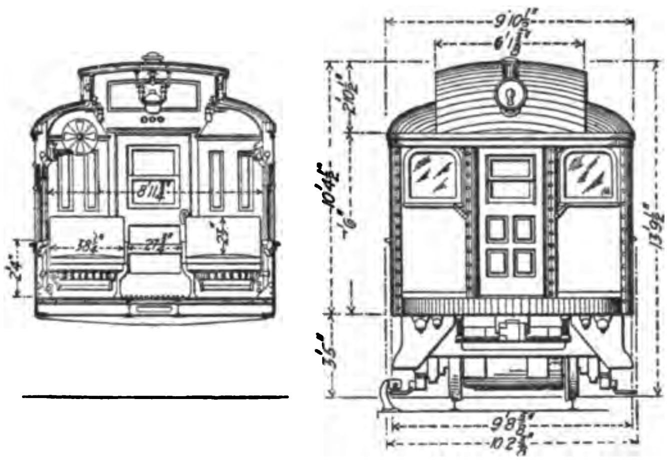


Fig. 86.—End View of All-Steel Motor Car Used on New York Central.

be used on the motor trucks and 33-inch wheels on the trailer trucks.

The table below shows the weights, complete and ready for service, of the New York Central motor car and trailer car.

TABLE XXVII

WEIGHTS OF COMPLETE CARS READY FOR SERVICE

	Motor Car Lbs.	Trailer Lbs.
Total weight, light	102,600	78,600
Total weight, loaded	111,560	87,560
Weight light, per passenger	1,603.1	1,228.1
Weight of car body	53,000	53,000
Weight of motor truck without motors	15,400	....
Weight of motors per truck	12,400	....
Weight of trailer truck	11,800	11,800
Weight per wheel, loaded — motor truck	16,195	10,945
Weight per wheel, loaded — trailer truck	11,695	

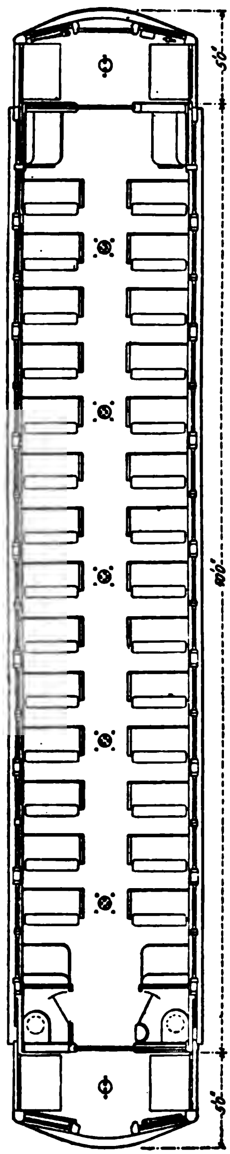


FIG. 87.—Plan View of All-Steel Motor Car Used on New York Central.

The weight of the electrical equipment of the motor car, exclusive of the motors, is 6,000 pounds at the motor end of the car and 4,000 pounds at the trail end of the car.

The following comparison of a steam and electric train of six cars each may also be of interest:

Steam.	Lbs.
Locomotive (average suburban type)	275,600
Six cars (standard type, loaded)	424,560
Total	700,160
Electric.	Lbs.
Four-motor cars	446,240
Two trailer cars	175,120
Total	621,360

This table shows a difference of 78,800 pounds, or 39.4 tons, in favor of an electric train having the same seating capacity.

Specifications for Interurban Electric Railway Passenger Cars

The following is a complete set of specifications for the construction of a modern car for heavy interurban service.

General Dimensions:

	Ft.	In.
Length of car body over corner posts	40	
Length of vestibule	4	6
Length of rear platform	5	
Length over vestibules, about, and not over	50	
Extreme length of car over buffers, about	52	
Width of cars over sills and sheathing	8	4
Extreme width of car not to exceed	8	6
Height of car from under side of sills to top of roof, about	9	4
Distance between truck centers as great as possible and clear car steps.		

Sills and Bottom Framing:

All sills and floor framing to be made of best long leaf yellow pine. Side sills to be made of one piece 5 inches x 8 inches and one piece 2 inches x 6 inches, with 6-inch x ½-inch steel plate running full length of car body securely bolted between.

The outside sill on left-hand side of car looking forward to extend from rear corner post under front vestibule to buffer. The right-hand outside sill to extend from corner post to corner post only. The two intermediate and two center sills each to be of 6-inch steel "I" beams, filled on each side with suitable yellow pine filling pieces, and extend full length of car under front vestibules and support buffer at front end of car. End sills to be made of oak 6 inches x 8 inches, re-enforced on under side with heavy steel angles, extending full width of bottom frame, and securely bolted thereto. All cross sills and intermediate framing to be made of 3¾-inch x 6-inch yellow pine and arranged to suit motors and trucks used. Floor framing to be well tied together with ⅝-inch rods running full width of bottom, with cup washer and nut at each end. Bolster to be made of steel plates with suitable iron filling blocks in shape and design to suit trucks, and sufficiently strong to prevent bending upward at center. Bolsters to be located in bottom frame, so as to carry car body as low as possible with 36-inch wheels swiveling under sills.

Trussing:

Inside trusses to be ½-inch x 2½-inch flat iron running full length of body, and down through side sills at either end, and through forged corner sill plates, having upward extending flanges over end sills. The under trusses are to be of 1¼-inch round iron securely fastened to sills, extending from bolster to bolster, and fitted with all necessary support and turnbuckles. The needle beams to be made 4-inch x 6-inch white oak, strengthened with ⅝-inch truss rods.

Flooring:

To be of ⅞-inch x 3¼-inch yellow pine in two thicknesses, with heavy building felt between. The first floor to be laid crosswise at bottom, and securely fastened to all bearings. The finished floor to be laid lengthwise of car, securely nailed and painted with two coats of lead and oil paint, in colors to suit purchaser. Under flooring to receive a coat of paint before being covered with building felt, also paint under side of top floor before laid. Also paint top of sills and both sides of both floors.

Body Framing:

All posts, corner, side, door, etc., to be made of white ash. Every second side post from corner to be made double with a neat panel inside and outside. Each alternate post to be single and run up back of top sash of side windows in such manner as in Pullman sleeping cars. Each post to have a $\frac{1}{2}$-inch rod running full length from car sill to top plate with washer and nut on each end. Each belt rail to be made of yellow pine in one continuous piece and capped with ash. Intermediate ribbing, plates, etc., to be made of long leaf yellow pine in continuous pieces without splice. Outside of car bodies below sash rest to be trussed with X-bracing and by filling in between same. Trussing and fillings to be gained over posts and securely screwed and glued. This sheathing and trussing to be thoroughly painted on the inside. The outside sheathing of the car to be made of $\frac{1}{2}$-inch x 2-inch poplar matched and molded, securely glued and nailed. Carlines and roof framing to be made of ash. Carlines to be placed about 10 inches between centers. At each side post to be a steel carline made of $1\frac{3}{8}$-inch x $\frac{5}{8}$-inch soft steel, forged in one continuous piece to shape of car roof, from side plate to side plate with foot at each end.

Roof:

To be made of steam railway passenger coach type, with steam type of hood, covering vestibules at both ends, roof to be covered with $\frac{1}{2}$-inch matched ceiling, securely fastened to all bearings, and painted with two coats of lead and oil and covered with No. 8 cotton duck. This is to receive three coats of best roof paint.

Vestibules:

Platforms at each end of car, to be inclosed by vestibules having round front with three single drop sashes across ends, sheathed on outside No. 14 sheet steel, and neatly paneled on inside in hard wood and painted same as outside of car body, or grained. The left-hand side of front vestibule looking forward to be closed with panel and sash to correspond with side of car. The right-hand side to have double steps covered by trap door hinged to end of car body and inclosed by double

folding doors. Rear vestibule to be inclosed at end same as front vestibule, and having double steps, trap doors and folding doors at each side of vestibule. Front vestibule floor to be flush with car floor.

End vestibule sash to be arranged to turn water readily and prevent blowing in when moving at high speed against wind. Rear vestibule floor to be about 6 inches lower than floor of car. The rear vestibule floor framing shall be separated from the framing of the car body proper; said vestibule shall be supported by at least four extra heavy steel beams running back to the bolster of the car and rigidly fastened to sills; said steel frame shall be re-enforced by wooden stringers, all to be of sufficient strength to support the vestibule absolutely, and car builder shall guarantee that said vestibule shall not sag from body of car for a period of two years. Steps on rear vestibule to be extra long, about 36 inches, or longer if practical.

Windows:

There are to be 14 windows on each side of car between corner posts arranged in pairs, and with two sash, the top sash being stationary and extending the width of two bottom sash, with single post running up behind top sash and concealed by art glass in upper sash, the arrangement being the same as in Pullman sleeping cars. All sash to be made of mahogany and finished on inside in natural wood, and on outside filled and painted in same manner as outside of car body, or finished in natural wood. The lower sash to raise not less than 22 inches, or to such a height that the bottom of sash when raised shall be not less than 4 feet 3 inches above car floor. Sash to be fitted with National sash locks, and all necessary springs, locks, lifts, etc. Deck sash to be of mahogany, hinged at bottom and secured by bronzed spring catches which are operated by bronze hooks. Shape of side windows and deck sash to be oval tops like latest Pullman cars.

Glass:

All windows and doors, except door sash, are to be glazed with best polished American Plate Glass ¼-inch thick, set in rubber, and secured with neat moldings and bronze screws. Deck sash to be glazed with art glass; also top stationary sash

in side windows to be glazed with leaded art glass. A duplicate removable sash for all side windows and vestibule front windows for winter service shall be furnished by the car builder, glazed with E. A. No. 1 glass, in mahogany and to be secured for winter use by an approved design of such a nature as will not deface or injure the outside finish of the car. The vestibule windows shall be so constructed as to be absolutely water tight when closed, similar to vestibule doors. Car builder shall guarantee that all doors shall be absolutely water proof.

Curtains:

All side windows to be fitted with Pantasote curtains mounted on extra heavy spring rollers and with roller-topped fixtures. The end windows and door back of front vestibule to be fitted with similar curtains arranged to shut off light from inside of car.

Ceiling:

Empire style, deck sash in pairs with oval tops, and with ceiling to be made of three-ply veneer, painted and tinted in some shade of blue, green or brown, and decorated in color and gold to suit purchaser.

Interior Finish:

All interior finish of car, panels, doors, sash moldings, etc., to be of solid select dark mahogany in natural color, varnished and rubbed down with pumice stone and oil to a smooth dead finish. The principal panels in interior of car to be plain, rich, dark mahogany. No veneers are to be used in these cars except ceiling, as specified herein. Special attention to be given in selecting all large panels of dark handsome grain. General interior to be rich, plain and smooth with few decorations.

Doors:

To be made of 1¼-inch solid mahogany and glazed with bevel edge plate glass, to be finished same as interior finish of car. Rear end of car to have double automatic sliding doors in center. Front end of car to have double automatic sliding doors in center. Smoking partition to have single door to

swing toward rear of car only, and glazed in upper portion with large bevel edge plate glass. All doors to have extra heavy hinges or latest type of hangers, handles, stops, guides and fittings, also heavy bronze catches to hold doors open.

Smoking Compartment:

Certain cars to be divided into smoking compartment and main passenger compartment by partition located four windows back from the front end and made to correspond with the interior finish of the balance of car. Glazed with plate glass at each side and with single swinging door in the center; also glazed with bevel edge plate glass in the upper portion, this door made to swing toward rear of car only.

Baggage Compartment:

Certain cars to have baggage compartment in front and occupying the space of the smoking compartment in the other cars and with partition separating the baggage compartment from the main passenger compartment, finished on each side to correspond with the interior finish of each compartment, paneled on both sides of door, and glazed with plate glass and thoroughly protected on baggage side by iron bars; the door in center being made to swing towards passenger compartment only, and glazed in upper portion only with bevel edge plate glass. Interior of baggage compartment to be finished in ash or other hard wood, oiled and varnished, or painted a light lead color, all windows and doors to be thoroughly protected by iron rods or wooden slat guards. Door opening at each side of baggage compartment 48 inches wide and fitted with sliding door, having upper part glazed with glass same as balance of car. Baggage door heads to be finished to correspond with outside of car; to be protected on each side by heavy sheet steel extending half way to top of door post and having door sills covered by heavy steel plates. Each baggage compartment to be fitted with benches hinged to sides and made to fold against inside of compartment when not in use. Use hinged seats full length each side of compartment. Under baggage door sills to be so re-enforced as to prevent settling, also angle iron to protect lower edge of sill from wagon wheels backing against car at baggage door.

Saloon:

Each car to have a toilet room with oval leaded art glass window, located in rear left-hand corner of car looking toward rear end, paneled and finished to conform to interior finish of car, and to have transom top and sash for lighting interior and swinging door to open outwardly. Water cooler to be placed in alcove on outside of toilet room. Ventilator in roof over toilet room. Toilet room door to lock with a key.

Trap Doors:

Trap doors shall be placed in floors inside of car to conform with the position of the motors. No cross sills either of wood or steel shall be cut to provide for said trap doors, said trap doors shall be fitted with a strong ring and socket for lifting same, with the top level when closed; said ring and socket to be of extra strength.

Heaters:

At closed side in front vestibule to be located a hot water heater, with hot water pipes extending along sides of car, and protected by metal shields, the heater to be so arranged as to be easily removed in the summer. Heater to be supplied and installed by the purchaser.

Brake Staff:

To be of $1\frac{3}{4}$-inch round iron, forged, tapering from ratchet wheel, and be provided with 18-inch steel wheel. The pawl of the brake staff to be of suitable length and be fitted with best quality of $\frac{1}{2}$-inch twisted link chain.

Seats:

High back with head roll push-over type, with cushion, 34 inches long and 17 inches wide; corner grab handles of bronze, highly polished on springs with spring edge, and upholstered in plush. One reversible to be located at each unoccupied side window, except that all corner seats are to be with stationary back against partition or side of car.

Smoking compartment to have same seats located in same manner, but to be upholstered in first class grade of white woven rattan. All seats are to be supplied by the purchaser and installed by the company.

Parcel Racks:

All passenger compartments are to be fitted with bronze parcel racks of the continuous type, extending full length of each side of the compartment. All baggage compartments to have iron baggage racks or shelves conveniently located for carrying parcels or small express packages.

Steps:

Right-hand side of front vestibule and both sides of rear vestibule to be fitted with regular steam railway coach type of steps securely rodded together and fitted with safety treads of lead and steel, or Stanwood steel steps if desired by purchaser.

Fender:

Front end of each car to be fitted with a Providence heavy interurban car fender.

Draw Bars:

Both ends of each car to have Van Dorn's No. 11 radial draw bar; also a cast steel pocket or draw head, same as used on cars of Detroit United Railway, with socket for link and pin, is to be rigidly fastened on top of each buffer in center, and a forged link about 6 feet long and 2½ inches in diameter at center, with each end forged to fit the socket and admit coupling pin. Is to be suspended on hooks under side of each car.

Buffers:

Each car to have buffer of oak, faced with 8-inch channels full width of car and extend not less than 8 inches beyond vestibule sheathing.

Push Buttons:

Each side post in passenger compartment to have electric push bottons, provided with all necessary signal bells, dry batteries, etc., with all wiring easily accessible.

Trimmings:

All metal trimmings, both inside and outside of car, to be of bronze highly polished, and securely held in place by bronze screws, unless specified otherwise herein.

Window Guards:

The side windows of each car to be protected by five-rod iron window guards in sets for each double window, and hinged so as to drop down for cleaning windows.

Register:

Each car to have fare register with necessary rods and fixtures, to be supplied by purchaser, and installed by the company.

Grab Handles:

Each corner and vestibule post to be provided with bronze tube or hickory grab handles 24 inches long, and 1 inch in diameter, supported in bronze sockets, also horizontal grab handles on ends of cars in vestibules.

Trolley Board, Motorman's Steps, etc.:

Roof of car to be fitted up with trolley board of suitable design, full length of car roof, set in brackets and bolted to roof and steel carlines by strap bolts and insulated from same by large rubber washers. Two diagonal corners of car to be fitted with motorman's steps, roof mats, handles, etc., for access to trolley and roof of car. Front end of car to be provided with 14-inch foot gong and 5-inch conductor's signal bell.

Floor Mats:

Each passenger compartment to be supplied with strips of Manila matting, with zinc ends extending full length of compartments and width of aisle between seats, laid loose so that it can be quickly removed for sweeping and scrubbing floor of car.

Sand Boxes:

Front end of each car to be equipped with two Nichols-Lintern Air Sanders, and with all necessary attachments, and so arranged as to drop sand on rails immediately in front of leading wheels.

Headlight and Trolley Catcher:

Each car to be supplied with one Wagenhals Arc Headlight on front end, and one Wilson trolley catcher on the rear end.

Car Wiring:

Car builder shall wire cars for incandescent lamps—35 in number—to be arranged as hereinafter specified. He shall further supply all approved switches and fuse blocks necessary for the installation, and he shall use none but extremely flexible tinned rubber-covered wire of extra heavy insulation of sufficient size, and shall arrange such ear wiring, either by means of conduits or moldings in such a manner that same may be accessible at all times. Car builder shall wire the cars from a point at the trolley base on the roof to a point under the car, as per plan to be obtained by him from the purchaser. He shall also furnish the wire and all necessary labor and material for this work.

Car builder shall also furnish and install 35 incandescent 16 candlepower lamps, Edison base, 16 plain and 19 frosted globes, of special low voltage, exact nature of same to be specified hereinafter together with necessary wiring fuses and switches as approved.

Car lighting to be arranged as follows: 4 clusters of 4 lamps each in ceilings; said lamps inclosed in Holophane globes suspended from ceiling; 3 in passenger compartment and 1 in smoker; and 8 on each side, suspended from ceiling over center of seats, spaced equally on each side of car, including smoking compartment. One lamp in each vestibule to be so arranged by means of a double throw switch as to enable either one or the other to be used as desired.

Car builder shall also equip car complete with electric bells. One push button on each side of car adjacent to each seat; said push button to be inserted flush with woodwork, and to be of approved make; and two electric bells shall be furnished to be placed above inside end doors; said bells to be 4-inch inclosed box type, of approved make, and operated by not less than 4 dry batteries of approved manufacture.

Air Brakes:

Each car to be equipped with air brakes; each compressor to be suspended and incased in boxes underneath the car. Controlling valve in front vestibule only, and to be provided with air whistles; also hand brakes complete with wheel. Air brakes all to be supplied and installed by the purchaser; hand

brakes by the truck builder and car builder jointly, and are to be connected and attached by the car builder.

Painting:

Cars shall be painted in accordance with M. C. B. specifications, and of such colors as directed hereafter. Morley's white lead to be used throughout, special attention to be given car when in the white. Allow ample time for each coat to dry. Said cars to be given three coats of Morley's white lead and boiled linseed oil, outside with Sherwin & Williams finishings, and three coats extra heavy wearing body varnish outside.

Inside to be given three coats of No. 1 rubbing varnish; each coat to be thoroughly rubbed with pumice stone and oil; final finish to be left "eggshell." Numbering and lettering to suit purchaser. Outside color shall be Big Four Railroad. Roof to be painted three coats heavy lead and oil on canvas.

Material and Inspection:

All material entering into the construction of these cars to be first class in every respect, and all labor to be performed in first class and workmanlike manner. The cars to be subject to the purchaser's inspection at any and all times during construction.

Vestibule Curtains:

Outside vestibule curtains shall be of strongest possible material, and shall be arranged vertically in such a manner as to roll up when the door is open. Special attention shall be given to the fixtures of same in order to make them as strong as possible.

Inside Window Guards:

All inside end or partition windows to be provided with brass guards of three rods each; also partition windows in vestibule to be similarly protected.

Miscellaneous Equipment:

Each car shall be equipped with the following details: One complete system of railway lamps (signal), viz.: One green and white (inside), one red tail lamp, latest approved Adams & Westlake manufacture, stamped steel, together with 12 spare

lenses of each color, and lamps to be duplicate. Also furnish all sockets for the hanging of said lamps in place.

Three flags of No. 1 bunting steam road regulation size; one red, one white and one green, together with the supports for same as required and approved.

Two brass fire extinguishers of approved make, and supported in place inside of car as directed by the purchaser.

Six extra heavy iron cuspidors in each smoking compartment.

One water cooler, one glass and support therefor as approved.

One best quality Manila floor mat to extend entire length of center aisle.

One removable rubber mat of extra thickness for each vestibule.

One motorman's tool box in each vestibule.

One motorman's stool, extra heavy, for each car.

One emergency tool case with glass front, to be used in case of accident; said case to be of similar finish to the interior of the balance of car; each shall contain one saw, one bar, one sledge and one axe.

Two extra heavy motorman's switch irons, and approved steel spring clip and floor socket for same. One set in each vestibule. Switch irons to be made of $\frac{7}{8}$-inch steel with chisel point and neatly turned handle.

Twelve pieces of glass of each separate size contained in these cars are to be supplied with the cars without extra charge, packed in boxes and delivered with the cars.

Each car to have two small mahogany or bronze holders or pockets for time cards, folders, telegraph blanks, etc.

All lumber to be No. 1 sound, merchantable and free from sap.

With regard to the motive power, it will be noticed that four-motor equipments are advocated here on all double truck cars for the road under consideration, which is assumed to have average grades, possibly 5 or 6 per cent. maximum. Railway managers have gathered together reports of tests, and argued the point for some years, without coming to an agreement as to which is the most economical to operate. Figures

showing cost of operation, including power, platform expense, maintenance per car mile, car hour, seat mile, and even per occupied seat mile, have been presented without convincing very many either way, except the compilers of the figures themselves. The truth is that local conditions, including grades, necessary schedule speed and traffic density, should determine this question in each particular case, and while four-motor equipments seem to be the fashion at present, there are many cases where two motors would be more satisfactory, taking all things into consideration. Two-motor equipments on maximum traction trucks is an attempt to utilize nearly the total weight of the car for traction purposes, and such equipments, when conditions are right, as easy grades, and little snow, give the best results. But the engineering condition exists that as the torque of the motors approximates the traction coefficient of the wheels with the track, the power consumption per car mile increases rapidly, and the maximum traction coefficient possible depends on the condition of the railhead. When any comparison is made to find the difference in cost of operation between two-motor and four-motor cars, it is only fair when the cars have the same seating capacity, and the same total power. In general, when the proper conditions are followed the power consumed by the four-motor car will be somewhat in excess of the two-motor car, due to the increased weight of four motors over two motors of the same total power and also to the lower efficiency of the smaller motors.

To show how easily one may be misled when the conditions are slightly altered a test was once made on one of the high speed, third rail lines of the New York, New Haven & Hartford Railroad between two cars similar in all respects, except that one car was equipped with two motors only, both on one truck, while the other had both trucks equipped with similar motors to those on the two-motor car, thus doubling the power of the second car, and considerably increasing its weight. The schedule time was fixed, as were the number of stops, for the test was made in regular service. The length of the run was about 12 miles, with 7 stops. The schedule was made for the two-motor car, which had been maintaining it for some time with no difficulty. During the test, readings were taken from

speed recorders, volt meters and ammeters, and watt meters. All readings were carefully checked and instruments calibrated afterward. Speed-time curves, and others showing current, and voltage, and watts throughout the run, were plotted. At first the result was surprising, for the four-motor equipment consumed about 10 per cent. less energy per trip, than the two-motor, while maintaining exactly the same schedule. The curve of current consumed showed the reason plainly. The acceleration of the four-motor car was so high that, to avoid running ahead of the schedule, the power was frequently shut off, and the car drifted some distance, at intervals, while the two-motor car, which was geared to about 45 miles per hour, had to use current continuously between stops, in order to keep on time. The test was of interest, but the result did not show that four-motor cars would give better service on that line, unless it was desired to introduce a higher speed schedule. The fixed charges on the higher first cost of the equipment, as well as the increased maintenance, would more than counterbalance the slight saving in energy.

Under favorable conditions, two-motor cars can be made to give a more satisfactory and efficient service than cars with four motors, unless reserve power is needed at times, as in case of grades and snow. Then what is needed is greater tractive effort, and the four-motor car gives it. With every wheel a driver, and the whole weight of the car and its load available to increase the traction; with four motors of the proper rating to correspond with the weight to be moved, and the speed schedule desired; the railway manager has little cause to apprehend a serious interruption to the service. This is the point which impels many to adopt four-motor equipments, with the full understanding that even if more power is required, the additional expense is warranted if a fairly uninterrupted service can be given the public.

Some figures of interest in regard to the amount of power required at the switchboard to drive a large number of cars were obtained by the Brooklyn Rapid Transit Co.

When 224 elevated motor cars and 1,247 surface cars were in operation the average power station load was 51,171 amperes at about 550 volts. It is estimated that this current divides so that each elevated car takes an average of 67 amperes and

a surface car 29 amperes. As neither heating nor lighting was in use at the time the following estimate was made up, which is very nearly correct.

(a) Surface Car.

	Amperes.	Kilowatts per car.
Operation	29	15.95
Heating	6	3.3
Lighting	2	1.1

(b) Elevated Car.

Operation	67	36.85
Heating	15	8.25
Lighting	2	1.1

In Manhattan, New York, on the elevated system, the current consumed in the operation of an average loaded car is 35 amperes at 600 volts or 21 kw. For lighting 1.5 kw. is allowed, while 4.8 kw. must be provided for heating and 0.6 kw. for operating air pumps. This amounts to 27.9 kw. at the car, and, assuming that the car kilowatts represent 78 per cent. of the station kilowatts, it will be seen that there must be an output of 35.7 kw. at the station for each car in operation.

On the surface lines in Manhattan it is said that the power required for each car is about 16 kw. in summer and 25 kw. in winter. This includes current for both light and heat.

Car Heating and Lighting

The heating of an electric car is a problem surrounded by many variable conditions, and marked differences of opinion. It may be stated that there are only three methods of heating, viz., by electric heaters, hot water heaters and coal stoves. The selection of the best method for an average road, located in a cold climate, is by no means easily decided.

The more important factors which influence the decision are:

(1) First cost.
(2) Cost of heat.
(3) Convenience in handling.
(4) Type of car.
(5) Character of the run.
(6) The severity of the climate.

It will be admitted that it is possible to heat any car by

any of the three methods, though each has its advantages and disadvantages, but it may well be asked, what is meant by a properly heated car? Experience with your own particular public can best determine this, for the behavior of the majority will soon inform the management whether the heating is satisfactory or not.

All railroads have learned the lesson that it is impossible to heat and ventilate any kind of a car to the satisfaction of everyone in it. Such are the vagaries of the traveler that the car is always too hot for one and too cold for his neighbor. There is usually a considerable majority who are sane on the subject, and who do not complain unless there are good reasons for so doing. Experience has generally shown that in city service small cars making frequent stops should have a temperature varying between 50° and 60° F. during cold weather. In this service the distance ridden per passenger is short, and it is not customary to remove outer clothing, so the car should not be too hot. On interurban runs the situation is entirely different. The stops are infrequent; the time spent in the car is greater; the door is open but little; and the passengers remove their overcoats and wraps just as they do on a steam train, and expect to be kept as warm as if in their homes. This requires an average temperature of 68° F. On suburban runs the temperature is necessarily between those given for the two kinds of service described above, and depends on the length of the run, and the habits of the people in each particular locality.

Very often unsatisfactory car heating is not due to the apparatus employed, but to its careless manipulation. A car may be equipped with electric heaters and with a heater switch which gives, in its different positions, three changes in the quantity of heat radiated. The conductor, who is very busy, receives a complaint, and suddenly realizes that the car is too cold, and turns on full heat. A little later the car is too hot, and he cuts all the heat off. Another car may be equipped with stoves, or hot water, and it is evident that the satisfactory heating of that car depends entirely on the attention given the fire by the one in charge of it. The running of the electric heaters has been improved upon by some roads in recent years in the following manner. The despatcher notifies each termi-

nal, or certain central points, to display a sign indicating what position to put the heater switch, as "H 2," meaning "heater on second position," and conductors or motormen are expected to be guided constantly by these signs, which are changed only when the despatcher considers it necessary. On some roads the crew of the car do not control the heaters, as this work is performed by the inspectors, who carry keys to the switch boxes on the cars. This is an undoubted improvement, for the inspectors have time to devote to the heating question, while the crew are usually busy. Many interurban roads in the West have their cars heated by hot water, and the heater is carried in the front vestibule, in a single ended car, with the motorman. This has proved a satisfactory method of handling the heater, for the motorman can always keep informed as to the condition of the fire, and can easily give a few minutes of his time to it, during each run.

Taking up, in order, the principal points to be considered in the selection of a proper heating system, the first cost is an item which is not of so much importance unless combined with low cost of heat. It may be said generally that stoves are far the cheapest in first cost, and that electric heaters are next and hot water the highest. In cost of producing heat stoves are again the cheapest, hot water next and electric heat much higher. Certain comparisons and tests were once made on a large interurban car in severe weather. It was found that it required a current of 30 amperes at 500 volts, which supplied 24 heaters, to keep the car at the proper temperature. This current was equivalent to 15 kw., which cost, at the car, very close to one cent per kw.-hour, making the cost of heat 15 cents per hour, or $2.70 per day of 18 hours. Hot water heat was placed in the same car, and under like conditions, the same temperature was maintained at a cost of about 40 cents per day, or 2¼ cents per hour, for the coal consumed, there being no other charges, thus saving over 85 per cent. on cost of heat.

The above is evidently an extreme case, and the larger the car the greater will be the difference in cost. On the other hand, a smaller car may be sufficiently heated by a current of 10 amperes, or 5 kw., making the cost of heat, with electric heaters, but five cents per hour.

In general it will be found impossible to heat with the electric current as cheaply as with the other methods, but the reason why electric heaters are so extensively used is no doubt due to the third point mentioned, viz.: convenience in handling.

No other method of heating is so convenient. It is clean, easy to maintain and seldom gives trouble. For these reasons it is extensively used on most of our large city and suburban systems, and many of these systems are producing power at the car for considerably less than 1 cent per kw.-hour.

On the other hand, it is seldom realized that a considerable annual saving could be made in a large city system, using short cars, by substituting a stove for the electric heaters.

Hot water heat for interurban cars has been widely adopted during the past few years, and it has been very successful, for no system can distribute the heat so uniformly throughout the car. There are objections to it, of course, principal among which is the danger of freezing during the night if the fire goes down, and the car is not in a warm house. This is partly overcome by the use of brine, but the whole system needs more care and attention than either of the others. In some interurban cars, especially the double ended type, which include a passenger and smoking or baggage compartment, the hot water heater is usually placed close to the partition on one side or the other, and there are hot water heaters which are placed underneath the car, and fired from the ground. It has been said that an ideal system is one in which the water circulating through the pipes is heated by the current. It does not appear, however, that a successful system of this class has been yet put into use.

The other points mentioned as influencing the selection of the system of heating—the type of car, the character of the run and the severity of the climate—have been sufficiently touched upon in the general discussion above.

One move, which has been recently more general, is the adoption of portable storm sash placed outside the regular sash, during cold weather. This has a very considerable effect on the cost of heating a car, just as it has on a house. In cars with longitudinal seats, the only position available for electric heaters is in the panel just under the seat. Where there are cross seats they have almost invariably been placed beneath

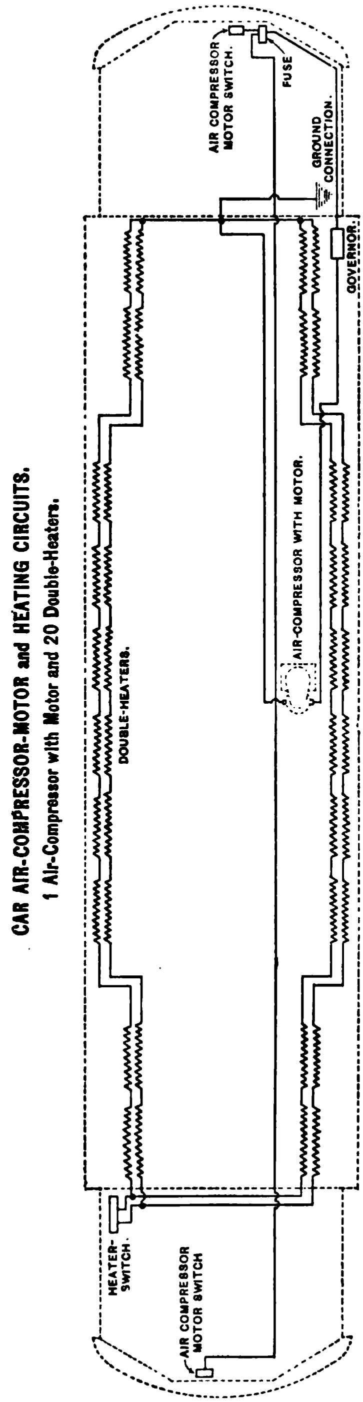


Fig. 88.—Air Compressor and Heating Circuits.

the seats, a location with some objections. Recently cars have been built with heaters located between the seats, attached to the truss plank. Where it is possible to do so, this is a far better location. Sometimes heaters have been placed beneath the floor, with a register above them, and the air supplied from outside. Heater wiring has had little attention given it in the past, and much of it has been complicated and badly done, causing at times a grounded heater on a wet day, which is sometimes unpleasant for the passengers. Fig. 88 shows a recent heater wiring plan. In selecting the type of electric heater it should be remembered that the amount of heat produced in the car is governed by the current consumed, and is absolutely independent of the type of heater.

Some heaters will radiate heat faster than others and run cooler, and a larger number of heaters will run cooler, and give a better distribution of heat than a smaller number which are forced to give out the same total amount of heat. In addition to selecting the proper number, a type should be chosen which is well built mechanically, and which can be easily repaired by the employees in the car house.

Probably the arrangement and method of lighting electric cars shows less changes than any other fixture, for until very recently almost no attention was paid to it from the beginning. The well-known arrangement consisting of one or more three- or four-lamp clusters attached to the head lining, in the center line of the dome, with perhaps a single lamp at each end alternately exchanged with the headlight at the opposite end, was in use on nearly all cars for many years. With the advent of longer cars it was finally decided to distribute the light more uniformily, and to increase the number of lamps. One of the first changes was to abandon the clusters and place the lamps in two parallel rows along the dome, each side of the center. Another change was to take the lamps out of the dome, and place them in a row under the deck lights on each side, or on the curve of the roof outside the deck plates. This gave a light over every seat, in a cross seated car, and made it more convenient to read. This plan is now very generally used, and in addition a smaller number of larger lamps are placed in a row in the center of the dome for general illumination. (See Fig. 89.) In the larger interurban cars where the empire, or

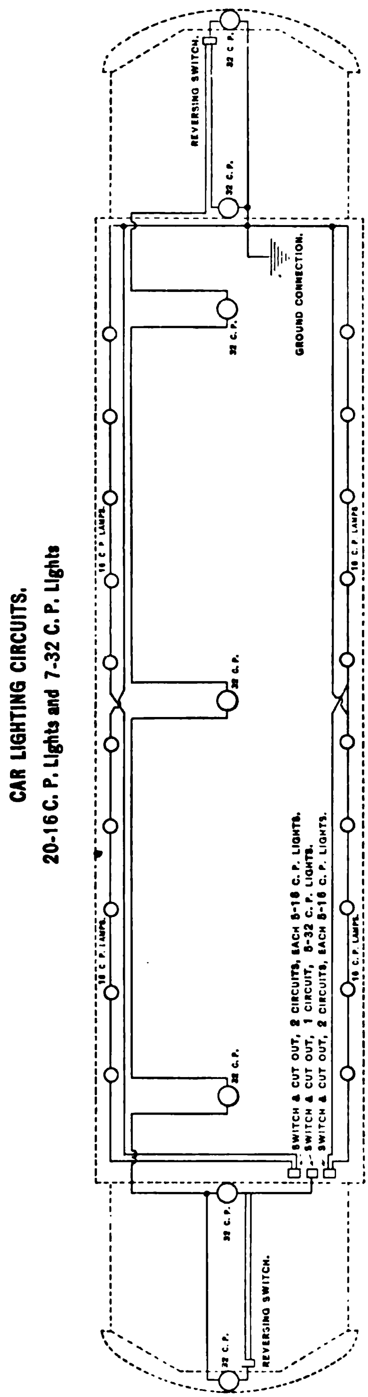


FIG. 89.—Car Lighting Circuits.

semi-empire type of ceiling is used, the arches from one side post to the other, across the car, are studded with nearly semi-circular rows of four or five lamps on each arch, which gives a very beautiful effect. Frosted globes and well designed fixtures have all assisted in this.

Probably the first attempts at artistic car lighting by electricity were made by those firms who supply apparatus for lighting steam trains, at the demand of the steam railroads. In the West, the competition between the steam roads has caused the construction of most luxuriously appointed trains, and no expense has been spared. Not the least of the improvements has been the electric lighting, and its development has been very rapid during the past few years. By far the finest effects can be seen in some of the Pullman sleeping or dining cars on those roads. While the arrangement and amount of light in the modern electric car has been greatly improved recently, there is still room for further improvement. Where light can be so easily obtained as in an electric car, there is no excuse for a dark, dingy car.

The marker lights or signal lights on a car should be independent of the power circuit. Especially is this true of the tail lights, and on account of safety an oil lamp, or low voltage electric lamp fed from a storage battery, is to be preferred.

Car Wiring

Little or no attention has been paid to this important subject, except in rare instances, until within the past year or two. The number of fires attributable to defective wiring in the past must reach into the thousands. Usually attended by more or less of a panic among the passengers, and damage to the car, it is difficult to account for the careless, unscientific manner in which the work was done, or why steps were not taken to correct it years ago. During this same period great improvements were continually being made in house wiring methods, under pressure from the insurance people, in order to render a house reasonably safe from fire. But electric cars were seldom or never insured; if they had been, a method of protecting the car would have been at once devised. The vast majority of cars have always been wired by the car builders, who receive the necessary cables, and other equipment, from

the electric manufacturing companies. The latter wired the early cars, and when the car builders took it up the same original methods were followed, and there are thousands of cars in service to-day, and new cars being wired, with the old familiar canvas-covered cables running along under the sills, or beneath the floor, held in place by leather straps tacked to the woodwork. If an iron rod or brace has to be passed, the cable is frequently in contact with it, the canvas and rubber insulation being considered sufficient. Motor and rheostat leads are run any way, the former hanging about the motor frame, rubbing on it every time the truck turns, and often where inside brakes are used, the live lever tie bar passes over the top of the motor, and rubs the leads whenever the brake is operated. The above is a very common condition of affairs, and when a lead periodically short-circuits the current, a new one is supplied as a matter of course, without apparently a thought that the trouble could be corrected. Rheostats are commonly attached to the woodwork beneath the car under conditions which almost insure the car taking fire, should they get very hot, and it is well known that there are times when the condition of track, and the grade, and possibly when using one motor, that the motorman cannot help heating the rheostats.

Not long ago some car builders made what they considered an improvement in wiring interurban cars. These cars had a pair of longitudinal center sills, and the space between them was kept sufficiently clear to contain the cables, and then was closed in with wood. It was an improvement so far, but they put the air brake pipes in the same space and allowed the cables to be in frequent contact with them, thus giving no protection except the insulation, between the positive side and the ground. It might be argued that there is no movement of pipes or cables, under the conditions, and for that reason it is safe. It is not denied that such cars might run years with no trouble, but it is not good practice, and all railroad men know that when a car is under headway the whole structure of pipes, rods and sills, becomes flexible, and each has a movement of its own more or less pronounced. This movement of the car structure was responsible for the fact, noticed some time ago, that solid copper wire nearly always gives trouble by breaking, when used about a car. It lacked the flexibility possessed by

stranded wire, and was unable to withstand the stretching it was subjected to.

The most careful work in wiring cars is very essential, and there is no reason why such wiring should not be made safe; and in order to do so, even if the insulation of wires and cables is of the best, they should be treated as bare wires, as the insurance underwriters say. The maze of iron pipes, rods and braces under modern cars renders it necessary to protect the wires from rubbing or chafing, with the utmost care. The working and straining of the car body; the swing of the trucks and brake rods; and compression of springs, must all be carefully considered, for no precaution in protecting the wires, however great, can make them absolutely safe.

Within the past year or two some great improvements in car wiring, made by the electrical manufacturers and some railroad companies, are noticed. In some interurban cars the entire surface beneath the floor is covered by a fireproof material resembling tough asbestos board. When multiple unit control is used the main wires are not made up in cables, but all wires between motors, contactors or rheostats, are run side by side, each wire in its own fireproof duct, made of the above material.

The possibility of serious loss of life if a fire occurred on a car of a subway train, was one of the reasons why car wiring was finally taken up by electrical engineers, and a system of wiring was soon evolved, which, while it is capable of improvement, was a long step in advance of other methods. It was simply the placing of cables and other wires in iron pipe conduits. This method, when fully developed, is the natural solution of the problem, when we consider the progress in house wiring, and is to be without doubt one of the standard methods of the future. It is almost the only method which can be adopted with safety if high tension currents are to be carried into the car. (See Fig. 90.) The number of city and suburban cars now being wired in iron pipe is continually increasing. It cannot be said to be a new idea, for it was tried a number of years ago with success, but its cost was considered prohibitive. At the present time, the safety of the passengers, and the preservation of the cars, is considered before cost. The National Board of Underwriters has drawn up a set of rules

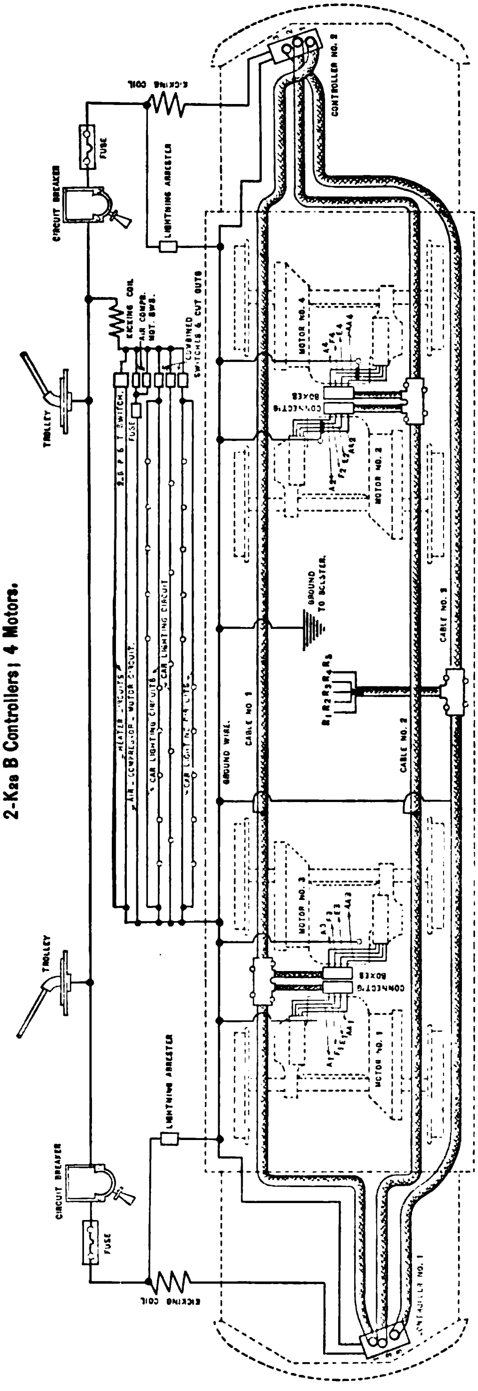


FIG. 90.—Method of Modern Car Wiring.

for car wiring which was greatly needed. These rules follow:

CAR WIRING SUPPLEMENT

TO THE 1903 EDITION OF THE "NATIONAL ELECTRICAL CODE."

Rules and Requirements of the National Board of Fire Underwriters for the Equipment and Wiring of Electric Railway Cars. As recommended by the Underwriters' National Electric Association.

CLASS C.—INSIDE WORK. LOW-CONSTANT-POTENTIAL SYSTEMS. 550 VOLTS OR LESS.

32. Car Wiring and Equipment of Cars.

a. Protection of Car Body, etc.

1. Under side of car bodies to be protected by approved fire-resisting insulating material, not less than ⅛ inch in thickness, or by sheet iron or steel, not less than .04 inch in thickness, as specified in Sections 2, 3 and 4. This protection to be provided over all electrical apparatus, such as motors with a capacity of over 75 horse power, each, resistances, contactors, lightning arresters, air-brake motors, etc., and also where wires are run, except that protection may be omitted over wires designed to carry 25 amperes or less if they are incased in metal conduit.

2. At motors of over 75 horse power each, fire-resisting material or sheet iron or steel to extend not less than 8 inches beyond all edges of openings in motors, and not less than 6 inches beyond motor leads on all sides.

3. Over resistances, contactors and lightning arresters, and other electrical apparatus, excepting when amply protected by their casing, fire-resisting material or sheet iron or steel to extend not less than 8 inches beyond all edges of the devices.

4. Over conductors, not incased in conduit, and conductors in conduit when designed to carry over 25 amperes, unless the conduit is so supported as to give not less than ½ inch clear air space between the conduit and the car, fire-resisting material or sheet iron or steel to extend at least 6 inches beyond conductors on either side.

NOTE —The fire-resisting insulating material or sheet iron or steel may be omitted over cables made up of flame-proof braided outer covering when surrounded by ⅛-inch flame-proof covering, as called for by Section 1, 4.

5. In all cases fireproof material or sheet iron or steel to have joints well fitted, to be securely fastened to the sills, floor timbers, cross-braces, and to have the whole surface treated with a waterproof paint.

6. Cut-out and switch cabinets to be substantially made of hard wood. The entire inside of cabinet to be lined with not less than ⅛-inch fire-resisting insulating material, which shall be securely fastened to the woodwork, and after the fire-resisting material is in place the inside of the cabinet shall be treated with waterproof paint.

b. Wires, Cables, etc.

1. All conductors to be stranded, the allowable carrying capacity being determined by Table A, of Rule No. 16, except that motor, trolley and resistance leads shall not be less than No. 7 B. & S. gauge, heater circuits not less than No. 12 B. & S. gauge, and lighting and other auxiliary circuits not less than No. 14 B. & S. gauge.

The current used in determining the size of motor, trolley and resistance leads shall be a per cent. of the full-load current, based on one hour's run of the motor, as given by the following table:

Size Each Motor.	Motor Leads.	Trolley Leads.	Resistance Leads.
75 h.p. or less	50%	40%	15%
Over 75 h.p.	45%	35%	15%

NOTE.—Fixture wire complying with Rule No. 46 will be permitted for wiring approved clusters.

2. To have an insulation and braid as called for by Rule No. 41 for wires carrying currents of the same potential.

3. When run in metal conduit, to be protected by an additional braid as called for by Rule No. 47.

NOTE.—Where conductors are laid in conduit, not being drawn through, the additional braid will not be required.

4. When not in conduit, in approved molding, or when not in cables surrounded by ⅛-inch flame-proof covering, to be protected by an additional flame-proof braid, at least $\frac{1}{32}$ inch in thickness, the outside being saturated with a preservative flame-proof compound.

NOTE.—This rule will be interpreted to include the leads from the motors.

5. Must be so spliced or joined as to be both mechanically and electrically secure without solder. The joints must then be soldered and covered with an insulation equal to that on the conductors.

NOTE.—This rule will not be construed to apply to connection of leads to motors, plows, or third-rail shoes.

6. All connections of cables to cut-outs, switches and fittings, except those to controller-connection boards, when designed to carry over 25 amperes, must be provided with lugs or terminals soldered to the cable, and securely fastened to the device by bolts, screws, or by clamping; or, the end of the cable, after the insulation is removed, shall be dipped in solder and be fastened into the device by at least two set screws having check nuts.

All connections for conductors to fittings, etc., designed to carry less than 25 amperes, must be provided with turned-up lugs that will grip the conductor between the screw and the lug, the screws being provided with flat washers; or by block terminals having two set screws, and the end of the conductors must be dipped in solder. Soldering, in addition to the connection of the binding screws, is strongly recommended, and will be insisted on when above requirements are not complied with.

NOTE.—This rule will not be construed to apply to circuits where the maximum potential is not over 25 volts and current does not exceed 5 amperes.

c. Cut-outs, Circuit Breakers and Switches.

1. All cut-outs and switches having exposed live metal parts to be located in cabinets. Cut-outs and switches, not in iron boxes or in cabinets, shall be mounted on not less than ¼-inch fire-resisting insulating material, which shall project at least ½ inch beyond all sides of the cut-out or switch.

2. Cut-outs to be of the approved cartridge or approved blow-out type.

3. All switches controlling circuits of over 5-ampere capacity shall be of approved single-pole, quick-break, or approved magnetic blow-out type.

Switches controlling circuits of 5-ampere or less capacity may be of the approved single-pole, double-break, snap type.

4. Circuit breakers to be of approved type.

5. Circuits must not be fused above their safe carrying capacity.

6. A cut-out must be placed as near as possible to the current collector, so that the opening of the fuse in this cut-out will cut off all current from the car.

NOTE.—When cars are operated by metallic return circuits, with the circuit breakers connected to both sides of the circuit, no fuses in addition to the circuit breakers will be required.

d. Conduit.

NOTE.—When from the nature of the case, or on account of the size of the conductors, the ordinary pipe and junction box construction is not permissible, a special form of conduit system may be used, provided the general requirements as given below are complied with.

1. Metal conduits, outlet and junction boxes to be constructed in accordance with Rule No. 49, except that conduit for lighting circuits need not be over $\frac{5}{16}$ inch internal diameter and $\frac{1}{2}$ inch external diameter, and for heating and air-motor circuits need not be over $\frac{3}{8}$ inch internal diameter and $\frac{9}{16}$ inch external diameter, and all conduits where exposed to dampness must be water-tight.

2. Must be continuous between and be firmly secured into all outlet or junction boxes and fittings, making a thorough mechanical and electrical connection between the same.

3. Metal conduits, where they enter all outlet or junction boxes and fittings, must be provided with approved bushings fitted so as to protect cables from abrasion.

4. Except as noted in Section *i*, 2, must have the metal of the conduit permanently and effectively grounded.

5. Junction and outlet boxes must be installed in such a manner as to be accessible.

6. All conduits, outlets, or junction boxes and fittings to be firmly and substantially fastened to the framework of the car.

e. Moulding.

1. To consist of a backing and capping, and to be constructed of fire-resisting insulating material, except where circuits which they are designed to support are nominally not exposed to moisture, they may be constructed of hard wood.

2. When constructed of fire-resisting insulating material, the backing shall be not less than $\frac{1}{4}$ inch in thickness and be of a

width sufficient to extend not less than 1 inch beyond conductors at the sides.

The capping, to be not less than $\frac{1}{8}$ inch in thickness, shall cover and extend at least $\frac{3}{4}$ inch beyond conductors on either side.

The joints in the moulding shall be mitered to fit close, the whole material being firmly secured in place by screws or nails, and treated on the inside and outside with a waterproof paint.

NOTE.—When fire-resisting moulding is used over surfaces already protected by $\frac{1}{8}$-inch fire-resisting insulating material, no backing will be required.

3. Wooden mouldings must be so constructed as to thoroughly encase the wire and provide a thickness of not less than $\frac{3}{8}$ inch at the sides and back of the conductors, the capping being not less than $\frac{3}{16}$ inch in thickness. Must have both outside and inside two coats of waterproof paint.

The backing and the capping shall be secured in place by screws.

f. Lighting and Lighting Circuits.

1. Outlets to be provided with either single lamps of not over 32 cp., the lamps being supported in approved porcelain receptacles, or with approved clusters.

2. Circuits to be run in approved metal conduit, or approved moulding.

3. When metal conduit is used, except for sign lights, all outlets to be provided with approved outlet boxes.

4. At outlet boxes, except where approved clusters are used, porcelain receptacles to be fastened to the inside of the box, and the metal cover to have an insulating bushing around opening for the lamp.

When approved clusters are used, the cluster shall be thoroughly insulated from the metal conduit, being mounted on blocks of hard wood or fire-resisting insulating material.

5. Where conductors are run in moulding the porcelain receptacles or cluster to be mounted on blocks of hard wood or of fireproof insulating material.

g. Heaters and Heating Circuits.

1. Heaters to be of approved type.

2. Panel heaters to be so constructed and located that when

heaters are in place all current-carrying parts will be at least 4 inches from all woodwork.

Heaters for cross-seats to be so located that current-carrying parts will be at least 6 inches below under side of seat, unless under side of seat is protected by not less than ¼-inch fire-resisting insulating material, or .04-inch sheet metal, with 1-inch air space over same, when the distance may be reduced to 3 inches.

3. Circuits to be run in approved metal conduit, in approved moulding, or if the location of conductors is such as will permit an air space of not less than 2 inches, on all sides, except from the surface wired over, they may be supported on porcelain knobs or cleats, provided the knobs or cleats are mounted on not less than ¼-inch fire-resisting insulating material extending at least 3 inches beyond conductors at either side, the supports raising the conductors not less than ½ inch from the surface wired over, and being not over 12 inches apart.

h. Air Pump Motor and Circuits.

1. Circuits to be run in approved metal conduit or in approved moulding, except that when run below the floor of the car they may be supported on porcelain knobs or cleats, provided the supports raise the conductor at least ½ inch from the surface wired over and are not over 12 inches apart.

2. Automatic control to be enclosed in an approved metal box. Air pump and motor, when enclosed, to be in approved metal box or a wooden box lined with metal of not less than $\frac{1}{32}$ inch in thickness.

When conductors are run in metal conduit, the boxes surrounding automatic control and air pump and motor may serve as outlet boxes.

i. Main Motor Circuits and Devices.

1. Conductors connecting between trolley stand and main cut-out or circuit breakers in hood, to enter car through approved bushings, or to be protected where wires enter car to prevent ingress of moisture.

2. Conductors connecting between third-rail shoes on same truck, to be supported in an approved fire-resisting insulating moulding, or in approved iron conduit supported by soft rubber or other approved insulated cleats.

3. Conductors on the under side of the car, except as noted in No. 4, to be supported in accordance with one of the following:

a. To be run in approved metal conduit, junction boxes being provided where branches in conduit are made, and outlet boxes where conductors leave conduit.

b. To be run in approved fire-resisting insulating moulding.

c. To be supported by insulating cleats, the supports being not over 12 inches apart.

4. Conductors, with flame-proof braided outer covering, connecting between controllers at either end of car, or, controllers and contactors may be run as a cable, provided the cable where exposed to the weather is incased in a canvas hose or canvas tape, thoroughly taped or sewed at ends and where taps from the cable are made, and the hose or tape enters the controllers.

Conductors with or without flame-proof braided outer covering connecting between controllers at either end of the car, or, controllers and contactors may be run as a cable, provided the cable throughout its entire length is surrounded by $\frac{1}{8}$-inch flame-proof covering, thoroughly taped or sewed at ends, or where taps from cable are made, and the flame-proof covering enters the controllers.

Cables, where run below floor of car, may be supported by approved insulating straps or cleats. Where run above floor of car, to be in a metal conduit or wooden box painted on the inside with not less than two coats of flame-proof paint, and where this box is so placed that it is exposed to water, as by washing of the car floor, attention should be given to making the box reasonably waterproof.

Canvas hose or tape, or flame-proof material surrounding cables after conductors are in same, to have not less than two coats of waterproof insulating material.

5. Motors to be so drilled that, on double-truck cars, connecting cables can leave motor on side nearest to king bolt.

6. Resistances to be so located that there will be at least 6 inches air space between resistances proper and fire-resisting material of the car. To be mounted on iron supports, being insulated by non-combustible bushings or washers, or, the iron supports shall have at least 2 inches of insulating surface be-

tween them and metal work of car; or, the resistances may be mounted on hard-wood bars, supported by iron stirrups, which shall have not less than 2 inches of insulating surface between foot of resistance and metal stirrup, the entire surface of the bar being covered with at least ⅛-inch fire-resisting insulating material.

The insulation of the conductor, for about 6 inches from terminal of the resistance, should be replaced, if any insulation is necessary, by a porcelain bushing or asbestos sleeve.

7. Controllers to be raised above platform of car by a not less than 1-inch hard-wood block, the block being fitted and painted to prevent moisture working in between it and the platform.

j. Lightning Arresters.

1. To be preferably located to protect all auxiliary circuits in addition to main motor circuits.

2. The ground conductor shall be not less than No. 6 B. & S. gauge, run with as few kinks and bends as possible, and be securely grounded.

k. General Rules.

1. When passing through floors, conductors or cables must be protected by approved insulating bushings, which shall fit the conductor or cable as closely as possible.

2. Mouldings should never be concealed except where readily accessible. Conductors should never be tacked into mouldings.

3. Short bends in conductors should be avoided where possible.

4. Sharp edges in conduit or in moulding must be smoothed to prevent injury to conductors.

NOTE.—The foregoing rules are laid down as embodying the principal precautions necessary in safeguarding street railway cars from the fire hazard of their own electrical appliances. It is not expected that old equipments will be rapidly brought up to this standard, but it should be required that all new equipments and repairs to old equipments closely follow the rules.

The methods of joining the motor leads to the cable taps have always been unsatisfactory. That most commonly used, the brass screw-connecting sleeve with no solder, and covered with several layers of tape, is a particularly crude method, making it very inconvenient to disconnect when trucks are removed from

the car. Several clamp connections, of various designs, are being used, into which the leads are soldered and no screws used, but these must be covered with tape, or a rubber jacket, made for the purpose. A few roads have used connection boxes for a number of years. These they manufactured themselves, and they were attached either to the motor frame or the car body. The boxes contain a row of brass terminals, to which are screwed the connections which are soldered to the motor leads and cable taps. All who have used such boxes realize their great convenience, and though for some reason the electric manufacturing companies apparently discouraged their use, they are now being frequently specified by the railroads on new equipment, and will no doubt come into general use.

The proper connections between motor leads and cable taps are usually indicated by the manufacturers, by brass tags attached to the leads which correspond to those on the taps. If these should become disarranged or lost, it is often puzzling to make the proper connections, especially if there is not sufficient time to ring out each wire to the controller with a magneto, or a battery and bell. The connection boxes before mentioned obviate most of this inconvenience, for the cable taps are permanently connected to the four terminals in the box corresponding to the two armature, and two field leads, of each motor (if the boxes are attached to the car body), known for No. 1 motor, as A_1, AA_1, F_1, and E_1 respectively. No. 2 motor leads are A_2, AA_2, etc. A_1 may be called the positive side of the armature and AA_1 the negative, while F_1 is the positive field lead, and E_1 the negative. When the motors are in series the current from No. 1 motor at E^1 is carried through the cable and controller to A_2, but when the motors are in parallel E_1 is grounded, as well as E_2. Throwing the reverse lever from forward to back position reverses the position of A_1 and AA_1, thus allowing the current to flow through the armature in the opposite direction, without altering the field connections.

If cables are found with no tags, and it is attempted to connect up properly by the cut and try method, which is often done, it is interesting to know the possible number of right and wrong connections of the No. 1 motor leads. Figs. 91 and 92 show these in a clear, simple manner, worked out by Mr. Cale Gough. It shows there are 24 different possible connections of

No. 1 motor leads. As one of the field leads of No. 2 motor, E_2, is usually permanently connected to ground, the possible connections of its leads are only six. The different pairs of diagrams, as (1) and (2), (3) and (4), (5) and (6), etc., show the connections for both forward and rear positions of the reverse handle, that is, if (1) shows the connections with the reverse forward, (2) shows the effect of throwing the reverse back.

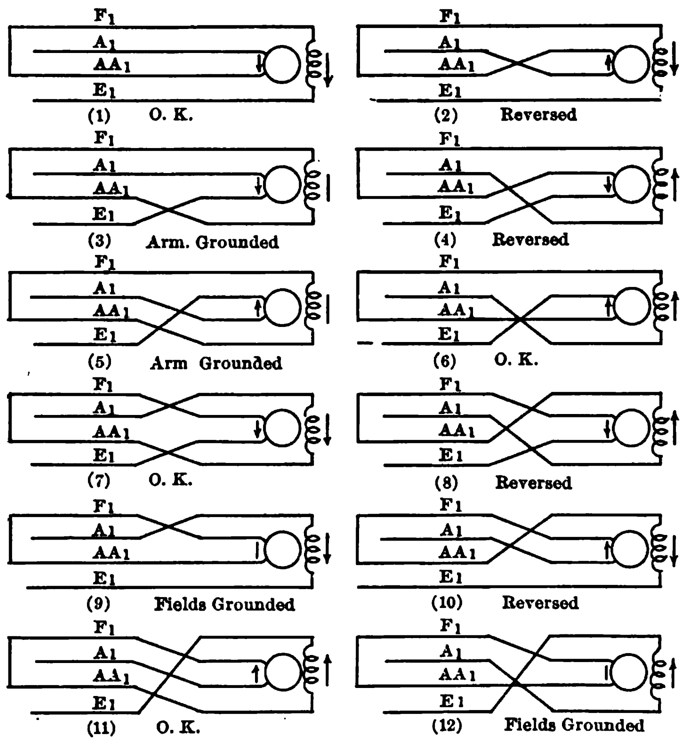


FIG. 91.—Diagram Showing All Possible Connections of Motor No. 1 Leads.

The arrows indicate the relative directions of the current in the field and armature coils. With both arrows pointing in the same direction, a forward movement of the car is assumed. Arrows pointing in opposite directions indicate that the motor is running in the reverse direction. We quote, in part, from Mr. Gough's explanation. (1) shows the proper connection of No. 1 motor; (2) shows the reversed connection caused by throwing the reverse lever back and causes the motor to re-

verse its direction of rotation. It also shows that the car might have easily been connected so, with the reverse lever forward, thus causing the car to move opposite to what the reverse lever indicated. It is easily remedied by connecting as (1). This explanation applies to each pair of diagrams in principle. An interchange of the leads AA_1 and E_1 (3), is made evident

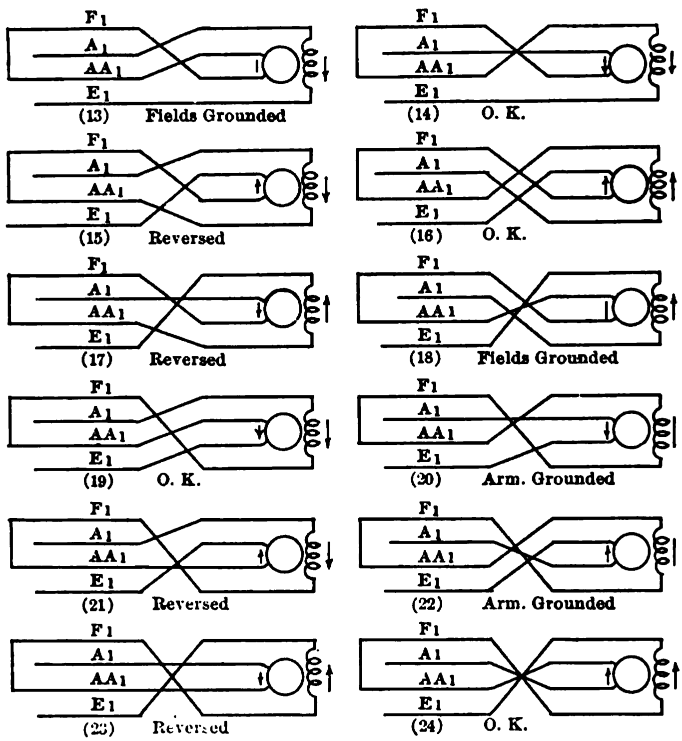


FIG. 92.—Diagram Showing All Possible Connections of Motor No. 1 Leads.

by the fact that with the reverse lever in the forward position the motor refuses to pull on the series points, and when the motors are thrown into multiple the fuse is blown or the breaker opens. This can be easily seen by the fact that E_1 is grounded in multiple and the current through A_1 and the armature is nearly short-circuited, there being only a part of the rheostats and the stationary armature for resistance, while the fields are short-circuited in themselves. The fact that when the reverse is thrown to the rear the motor tends to re-

volve in a reverse direction, distinguishes this misconnection from those shown in (5) and (20). There is, however, no way of distinguishing by the action of the motors, this crossing of the leads, AA_1 and E_1 from the complicated crossing of connections shown in (21) and (22). In either case the armature is grounded with the reverse forward, and throwing the lever to the rear reverses the motor. In the same way the connections shown in (4) and (21) cannot be distinguished from each other. The connections indicated in (5), (6), (19) and (20) may be recognized by the fact that the armature is grounded for one position of the reverse handle, while the motor revolves in the proper direction when the reverse is thrown. (7), (16) and (24) show connections permitting the motor to operate properly. It may be noted that in (7) and (16) the fields are placed in circuit on the trolley side of the armature. The connections shown in (7) are often used by those who believe, for various reasons, that the fields should be so placed in circuit. Four connections, (9), (12), (13) and (18), give grounded fields and short-circuited armatures. Such connections would cause the motor to act as a generator when being dragged by No. 2 motor. Two of these connections, as in the case of those causing grounded armatures, give forward direction to the car when the reverse is thrown to the rear, while the remaining two cause No. 1 motor to oppose No. 2 motor.

In general, the several possible connections may be divided into three distinct groups: (1), Those giving forward and reverse direction of rotation of the motor with different position of the reverse handle; (2), those by which the armature is grounded with one or the other positions of the reverse handle; and (3), those by which the fields are grounded by the position of the reverse handle. Those of the first class cannot be distinguished from each other by the action of the motor. However, should the motor operate in a direction opposite to that corresponding to the position of the reverse handle, the fault may be corrected by simply interchanging the armature leads of the motor. The connections of class two and three are distinguished from each other by the fact that the motor will not revolve when the controller handle is in the series position and the reverse is thrown in one or the other direction, while in the other case the short-circuited armature causes the

motor to act as a generator, retarding the movement of the car. The different connections in these two classes may be further identified by noting the position of the reverse handle when the motors operate, and by this means the mistake may be recognized as being due to one or the other of two possible connections. The only possible connections of the leads of No. 2 motor when the fields are permanently grounded, are those shown in (1), (2), (9), (10), (13) and (14). All of these may be definitely identified at once by observing the action of the motor, and the position of the reverse handle.

Even if the car house man becomes familiar with all these misconnections, rather than spend so much time in studying possible mistakes, it would be more satisfactory to keep the leads properly tagged, or use a connection box, and mark that.

Railway Motors

At the present time the so-called standard type of continuous current motor for street and interurban railways may be said to be fairly well developed along the lines justified by past experience. Other improvements will be made as time goes on, but no very radical departure from existing forms is in sight. Formerly the chief enemy of the motor designer was water or moisture. The appearance of the Westinghouse motors Nos. 3 and 12 and the General Electric 800 and 1000 gave us the first inclosed waterproof motors, and the problem of heating and ventilation arose. The capacity of a railway motor may now be said to be directly dependent upon its rise in temperature due to the current. This capacity or power may be increased by proper ventilation, but for a number of years no attempts were made by the manufacturers to provide ventilation. More recently attention has been given to this point with good results. Insulation has been improved until it is practically impervious to moisture, but it becomes carbonized by excessive heat, invariably resulting in a breakdown.

Few railway men realize that the two principal manufacturers of railway motors have each to offer from 10 to 15 different sizes or types. Each of these types can be varied as to the number of turns in the armature and field winding, as well as in the sizes of wire, even for one standard voltage of 550 to 600. One type of motor may be adapted to four or five differ-

ent gear ratios, two or three numbers of turns per armature coil, and several different field windings, so that it may be capable of perhaps 15 or 20 variations. As a result of this there may be upwards of 100 different motors offered the engineer who undertakes to select the best type for a given service. Speed, current, armature turns and gear ratio, are all interdependent of each other, and it is the popular combination of these that determines the selection.

It can therefore be seen how important it is to intrust the selection to an engineer of especial ability in these matters. On all large problems the best engineering skill is provided both by the road and the manufacturers for deciding the question. But it would be impossible to estimate the number of smaller systems and interurban roads which are continually under unnecessary expense due to their own shortsighted policy in this respect, or to that inherited from their predecessors.

The speed-time curve, some examples of which will be given later, is a beautiful mathematical demonstration from which is gained most of the information governing the choice of a motor. Such curves have been worked out theoretically which proved remarkably close to the curve obtained by actual test. This is an example of the highest order of engineering. A curve worked out for an ordinary interurban road passing through a rolling country, is not always reliable, due to the impossibility of making the working conditions agree with the theoretical. For example any motorman can so utilize the power on different trips as to require a different speed time curve to fit each trip. Especially can he cut out the drifting portion of the curve. The only remedy for this is a strict enforcement of necessary regulations for the proper handling of the car, which is often a difficult matter to carry out.

The subject of gear ratios is not always given the importance it deserves. It has been said that among all the motors made available by the manufacturers there are no less than 48 different gear ratios, varying from 1 to 1, or gearless, to 1 to 4.78. These ratios require nearly 60 combinations of gear and pinion.

An interesting analysis of the effect of changing the gear ratio on a series railway motor equipment has been written by Mr. J. C. Huffman. In order to bring out the subject clearly he assumes a certain equipment consisting of four 60

horse power 500 volt motors. Total weight of car 29 tons. Five changes of gearing were found practicable, ranging from 14:68 to 30:52. Acceleration is assumed at one mile per hour per second, and current value such as, if running continuously at 300 volts, would not cause the temperature to rise above 70° C.

Fig. 93 shows graphically the effect on speed and current consumption of these different gear ratios. In this case the speed and the square of the current are plotted against time. It shows the increase of speed with the increase of gear ratio

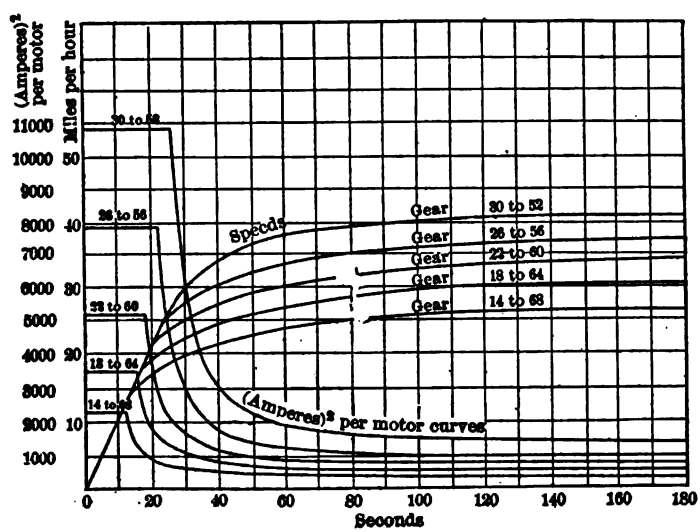


FIG. 93.—Effect of Gear Ratio on Speed and Current Consumption.

and that the increase of speed is obtained at the expense of increased current. A comparison of the heating effect, which is proportional to the current square, is also shown in Fig 93. This effect increases very rapidly with increased gear ratio, especially at starting. It serves to show why high-geared motors, such as are used in interurban service, should be given a low initial acceleration by means of the controller and rheostats, so as not to cause excessive drop on the line in starting, with its bad effect on other cars running, and the excessive momentary loads it imposes on the rotary converters.

Fig. 94 represents curves of train resistance and tractive

effort. The train resistance is in pounds per motor for a 29-ton car. The tractive effort curves are also in pounds per motor in order to show better the relation of speed to tractive effort when the gearing is changed. These curves show that for a given speed of the car the tractive effort increases when the gear ratio is increased. The fact that the tractive effort does increase with a greater gear ratio while the same speed is maintained can be accounted for by noting the rapid increase in the current square values in Fig 93. Fig. 94 also indicates the maximum speeds available with different gear ratios. The

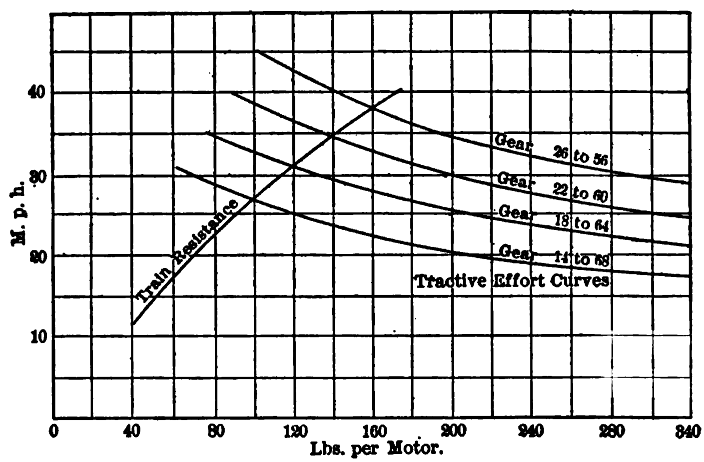


FIG. 94.—Train Resistance and Tractive Effort.

points of intersection of the train resistance curve with a tractive effort curve of each gear ratio is the highest speed which can be made with that gearing. In other words, at the point of intersection the tractive effort just balances the train resistance.

Fig. 95 is an example of speed-time and power-time curves for one gear ratio.

The effect of changing a gear ratio on a car equipment is as follows:

An increase in gear ratio causes an increase in speed with a corresponding decrease in tractive effort, with the same value of current.

It also causes increased tractive effort for the same car speed.

It gives an increased available maximum speed with an attendant increase in current, and consequently increases the heating of the motor.

Where low schedule speeds are required, necessitating low gearing, care should be taken not to have the gear ratio too low, for the condition might arise that the car was moving at the specified speed and the armature revolving at a rate in excess of its safe limit. This is especially important when cars are to operate on down grades.

In general it may be assumed that the best gear ratio to use

29 Ton Car. 4—60 H.P. Motors. Gear Ratio 14 to 68. Wheels 33."
Initial Acceleration 1 mile per hour per second. All stops 10 seconds.

Length of run — miles	¼	½	¾	1
Time of run — seconds	70	107	142	177
Schedule speed — m.p.h.	12.8	16.8	19	20.3
Average K.w. per car	40.7	40	39.3	38.1
Watt, hours per ton mile	110	82	71.4	65

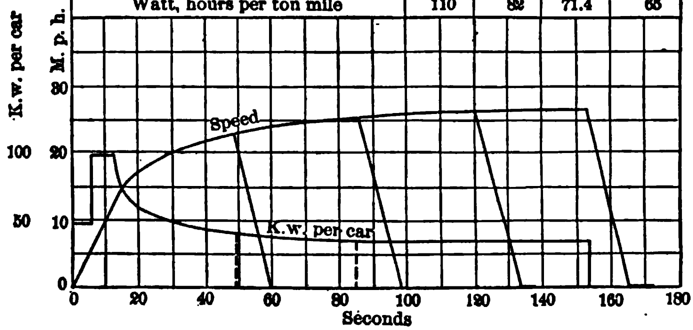


Fig. 95.—Speed Time and Power Time Curves.

on a given equipment for a given schedule speed is the lowest gearing that with a fair margin will maintain the specified schedule.

The capacity or power of railway motors is limited in two ways making necessary two methods of rating. In city service where speeds are low, acceleration high and stops very frequent, it is sufficient to rate the motor in accordance with the horse power it will develop for one hour without increasing its temperature above 70° C. The highest initial acceleration is produced by the maximum current, which is defined by the commutation limit of the motor. The second limitation is met

with in interurban service and is due to the heating of the motor caused by internal losses. This necessitates a rating based on a value of current input and horse power output at an average voltage of about 300, such as will not cause a temperature of over 70° C. on a continuous run in service. This latter rating for the same motor is very different from the

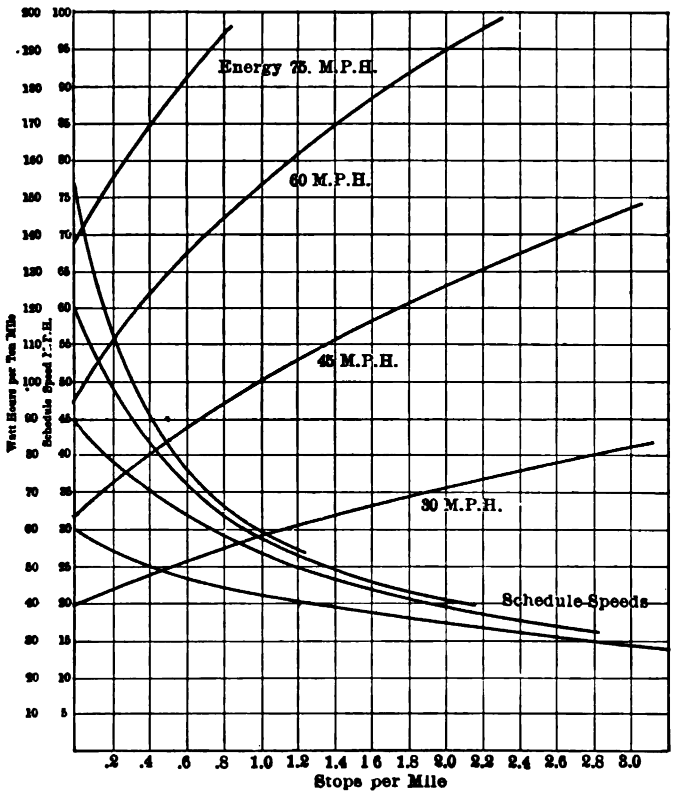


Fig. 96.—Typical Speed and Energy Curve for Single Car Operation.

former, being usually only 40 to 50 per cent. as high. Forced ventilation has been tried with promising results and experiments along this line are still being carried on.

Fig. 96 contains a set of typical speed and energy curves for single car operation from which much information may be obtained. These curves were originally worked out by Mr. A. H. Armstrong, and refer to runs made on a tangent level track.

If we assume a maximum speed for the car and the number of stops per mile of 10 seconds duration each, we easily find the possible schedule speed, the average energy consumption per ton mile, the average power consumption per ton at the schedule speed, and the average power consumption of the car, its weight being known.

As an example assume a 30-ton car with a maximum speed of 45 miles per hour and one stop in two miles. The vertical ordinate corresponding to .5 on the base line cuts the schedule speed curve belonging to 45 miles per hour maximum speed at

FIG. 97.—Typical Efficiency Curve of Railway Motor.

33 miles per hour schedule speed. The same vertical ordinate cuts the 45 miles per hour maximum speed curve at a point corresponding to an energy consumption of 85 watt-hours per ton mile. From these data we easily calculate the power consumption per ton at 33 miles per hour or 2.8 kw. from which the power required by the 30-ton car is found to be 84 kw.

A number of interesting points are brought out by these curves relative to schedule speeds possible for different maximum speeds. With one stop in 8 miles it is possible to maintain a schedule of 61 miles per hour with maximum speed of 75 miles per hour, and a schedule of 28 miles per hour with a maximum of 30 miles per hour. But if stops are increased

until they average 1 per mile it will be seen that with 75 miles per hour maximum the schedule speed possible has dropped to 29 miles per hour, while the 30 miles per hour maximum permits a schedule speed of 22 miles per hour.

The efficiency of the railway motor by careful design and the adoption of numerous improvements, such as laminated pole faces, cast steel magnetic frames and ventilated armature cores, has been brought up to the point where any considerable increase cannot be expected. Fig 97 is a typical efficiency curve giving the efficiency at all loads.

Regarding the mechanical details of the ordinary railway motor much could be said. Improvements have been slow for

Fig. 98.—Sheet Steel Gear Case.

the reason that it seemed advisable to develop the electrical features first. These mechanical details are very few in number, for the motor is nothing but a revolving shaft inclosed in a casing. They include the mounting of the motor frame on the axle by two bearings and the support of its other side by some method of suspension to the truck frame. The bearings for the armature shaft and its connection to the axle through a pinion and gear, as well as the gear case which incloses the latter. The size and location of the openings in the motor frame by which the interior may be inspected. These are practically all the operating man is interested in.

The design and lubrication of the bearings have been described under "Car Lubrication." The diameter of the armature shaft, especially at the gear end, is most important as the many cases of shafts twisted off or bent have shown. The service required is very severe, especially when pinions are worn and gears become loose, and in the past the shaft, as well as the axle, was often too small to withstand such conditions. A decided improvement was made when the pinion was applied on a taper fit and held with a key and lock nut.

A seemingly unaccountable policy of the manufacturers has

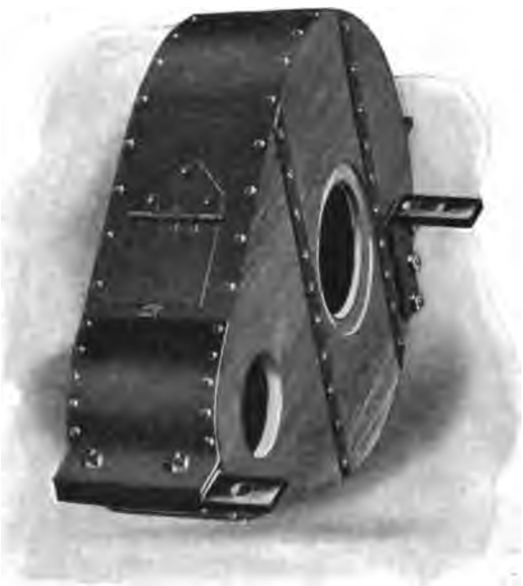


FIG. 99.—Combination Wood and Steel Gear Case.

been the retention of the malleable iron gear case through many years. This has been a prolific source of trouble through breakage, and yet only recently have gear cases made of sheet steel, or wood with a steel frame appeared on the market. Figs. 98 and 99 show respectively the all-steel and the wood-steel construction. These, if damaged, can be repaired with little trouble, but the malleable iron case was generally hopeless if a lug broke off or it was otherwise injured. In some

instances gear cases are used having sheet steel around the edge and canvas sides.

Single Phase Commutator Motors

An innovation in the railway motor field has resulted during the past two years from the introduction of single phase alternating current motors. Several types have been tried, including the repulsion motor, but the two principal manufacturers in this country seem to have now adopted the compensated series motor with slight differences in the details of construction. The motor is not a recent invention in its main features but had never been put to commercial uses, and it has prop-

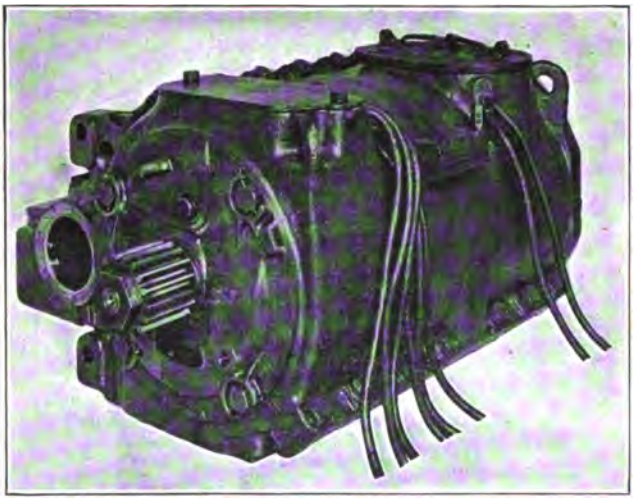


Fig. 100.—75 h. p. Single Phase G. E. Motor.

erties very similar to a series wound continuous current motor. Any series wound motor holds its direction of rotation unchanged when the polarity of its main terminals is reversed, and therefore will operate with alternating current. To keep down reaction and eddy currents and give a good power factor, it has been found desirable to design the motors with very powerful armatures and rather weak fields and then compensate the inductive reactance of the armature with an auxiliary field winding, and to make minor structural changes.

Figs. 100 and 101 show a 75 horse power single phase motor

manufactured by the General Electric Co. The magnet field consists of an iron cylinder built up of thin annular laminations insulated from one another by japan. The interior portions of these punchings which are thus securely bolted together, are so shaped as to form four poles, which latter are slotted for the reception of the compensating field windings. This laminated field cylinder is contained in an outer steel casting which forms the structural frame proper of the motor.

This casting is in two halves, being split on the diagonal in a manner indicated in Figs. 100 and 101. These halves are

Fig. 101.—75 h. p. Single Phase G. E. Motor.

in the assembled motor, securely clamped together by frame bolts.

Fig. 102 shows diagrammatically the main or exciting field and the compensating field windings. The exciting winding is provided in the form of a concentrated coil, somewhat similar to those found in ordinary direct current motors, while the compensating winding is of a distributed character, being composed of copper bars drawn through the overhung slots constituting the face of the pole proper.

The armature core is of the iron-clad type, having a series drum winding and being similar in all respects to the General Electric Co.'s standard direct current railway motor armature design and construction. The armature is removed from the motor by first removing one of the frame heads.

There are four brush holders, each carrying four brushes. The holders are of cast brass and adjustable. They are clamped on mica insulating studs, which latter are supported on a revolvable yoke. The brush holder cables are readily dismantled, permitting any individual holder to be removed.

The armature shaft bearings are carried on frame heads made of malleable iron. The linings are composed of unsplit bronze sleeves finished with a thin layer of babbitt metal. Large oil wells are provided in the frame heads for the reception of oily wool waste, which makes contact with a large surface on the

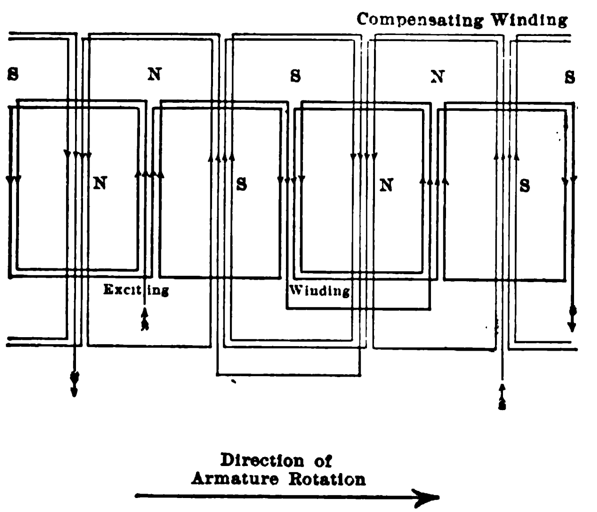


Fig. 102.—Diagram of Main Field and Compensated Field Windings in G. E. Single Phase Motor.

shaft through an opening cut in the low pressure side of the bearing linings. The axle bearings are provided with split linings and are held in place by cast-steel caps tongued and bolted to vertically planed and grooved surfaces on the frame. Here also, oil wells and oily wool waste lubrication are used.

Fig. 103 shows a line of single phase motors manufactured by the Westinghouse Co. Fig. 104 shows a 100 horse power single phase Westinghouse motor of late design. The mechanical construction of this motor is excellently shown in Figs. 104, 105 and 106. Referring to Fig. 105, the large bunched

coils are the main field coils, while the distributed coils are the compensating coils.

Sparking has always been a serious defect in the operation of single phase series motors. However, the new motors are

FIG. 103.—Line of Single Phase Motors Manufactured by the Westinghouse Company.

not troubled in the least in this respect. The Westinghouse motor employs resistance in series with the armature leads to prevent sparking due to the current produced in the coil short-circuited by the brushes. This resistance when in series with the whole armature does not cut much of a figure, and,

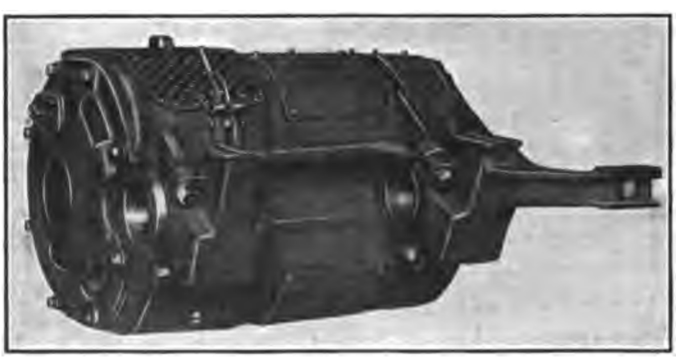


FIG. 104.—100 h. p. Westinghouse Single Phase Motor.

therefore, will not affect the efficiency of the motor to a noticeable extent, but when placed in series with one short-circuited coil it will cut a very great figure, and since it is greater than the resistance of the coil itself, it will have a marked effect upon

the value of the current flowing in that circuit, thus very materially reducing the sparking.

The General Electric Co. does not use resistance leads to cut down the current in the short-circuited coil, but accom-

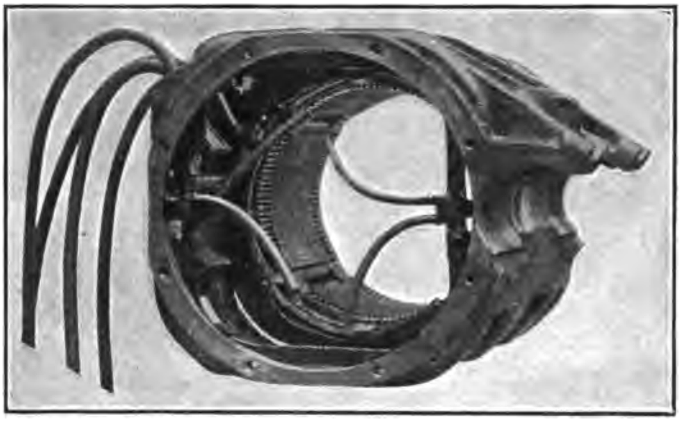


FIG. 105.—Frame of 100 h. p. Westinghouse Single Phase Motor.

plishes the same result by using only one turn on the armature per commutator bar, thus reducing the e. m. f. generated in

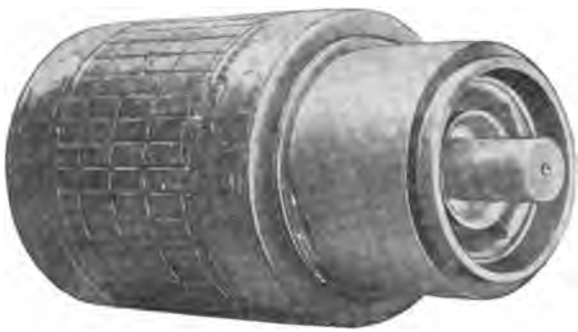


FIG. 106.—Armature of 100 h. p. Westinghouse Single Phase Motor.

the circuit closed by the brush, and consequently reducing the sparking current by a like amount.

The characteristic performance of a single phase compensated series motor is in every way similar to that of an ordinary d. c. traction motor of the series type. Fig. 107 shows the

performance of a 75 horse power a. c. compensated series motor when operating with alternating current, and Fig. 108 shows the performance of the same motor when operating with continuous current.

These motors are somewhat heavier than continuous current motors and a few per cent. less efficient, but when using trans-

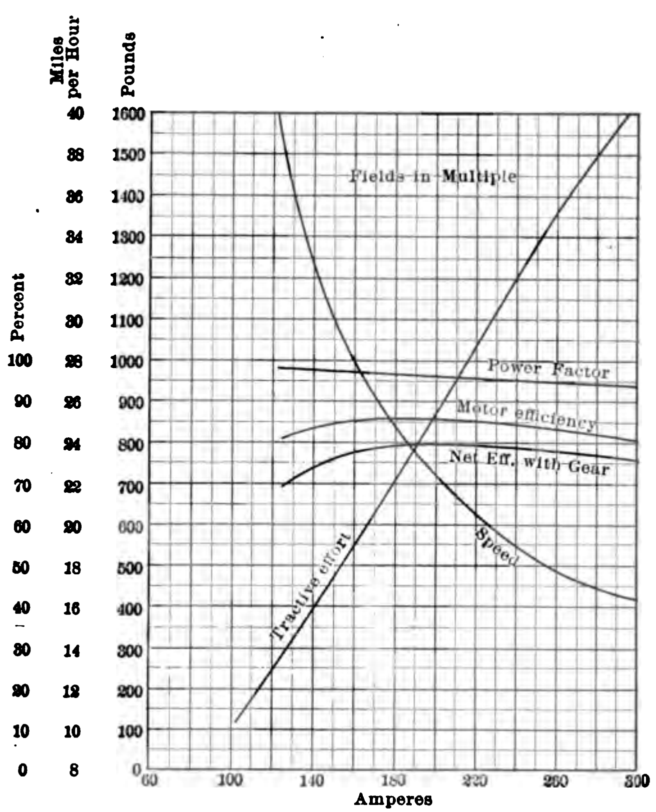


FIG. 107.—Performance of 75 h. p. Single Phase Motor with Alternating Current.

former voltage regulation they do not require an abnormal current in starting and accelerating. They require a static transformer between them and the source of current supply, since it is impracticable to use a high voltage on the commutator. For this reason they are wound for low voltage each, the motors in multiple at full speed on alternating current, and perma-

nently connected in series when operating with continuous current.

The latter quality—the ability to operate with both kinds of current—is most important. When variable voltage control is used with alternating current it necessitates an additional set of rheostatic control apparatus. It is understood that the practice now is, when it is necessary to operate on both currents,

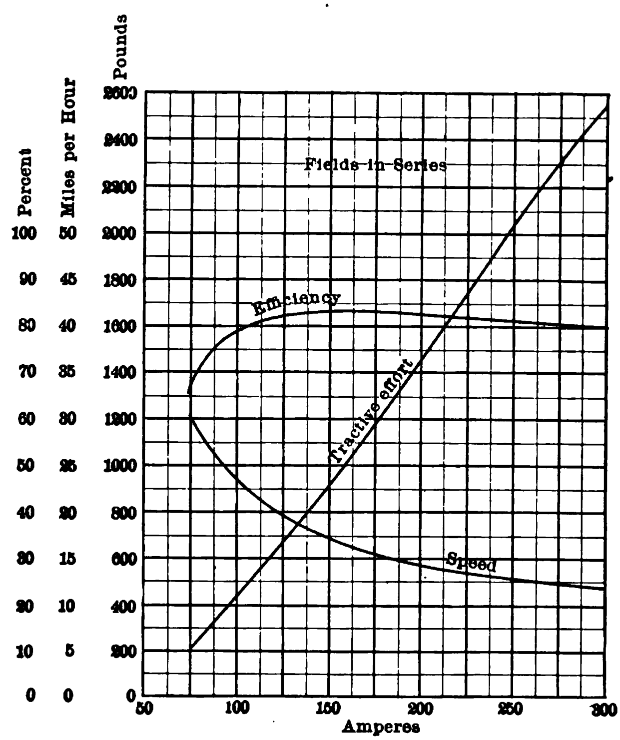


Fig. 108.—Performance of 75 h. p. Single Phase Motor with Direct Current.

to use only rheostatic control for both in order to avoid complication of apparatus. The advent of these alternating current motors opens up the whole problem of long distance electric railways, by greatly reducing the cost of conductors due to the possibility of using a high tension working conductor. One of the most recent developments along these lines is the adoption, by the New York, New Haven & Hartford Railroad, of

single phase series wound locomotives for its suburban service. These locomotives will take current from the trolley wire at 11,000 volts and will transform it on the locomotive. No substations or feeders will be required on the 22 miles of four-track line about to be equipped.

Figs. 109 and 110 are typical curves published by Mr. P. M. Lincoln to illustrate the difference in power required by a car equipped with continuous current apparatus and one having single phase equipment. They show the acceleration, drifting and braking, as well as the power consumed by each car on a similar run. The weight of the continuous current car is 35 tons and that of the alternating current car about 18 per cent. greater. The length of the run is two miles in each case, and the schedule speed 30 miles per hour.

As will be seen from the performance curves, shown in Figs. 107 and 108, that due to the method of control, the speed of the car, under circumstances requiring the same tractive effort, will be roughly two-thirds with 600 volts direct current of its value with normal voltage alternating current. This arrangement is usually what is desired, since the single phase equipments which are required to operate on both direct and alternating current, usually operate on alternating current in the open country, where a high speed is required, and on direct current in cities or towns, where the speed is necessarily limited.

The rheostatic loss in accelerating the continuous current car is entirely eliminated in the alternating current car. Were it not for this fact one would expect that the alternating current car being 18 per cent. heavier would take 18 per cent. more power. The actual difference in the areas under the power curves shows about 10 per cent. more energy for the alternating current car. If the run was one mile the energy consumption would be about equal, and if less than one mile the advantage is on the side of the alternating current car, on account of the rheostatic loss of the other. The difference in weight of the two equipments, 18 per cent., has been greatly reduced and is now probably not over 10 per cent.

The ordinary systems of a single and multiple unit control have been successfully adapted to the a. c. motor. The hand control of a. c. motors operating on an a. c. system, is extremely simple. In this case the voltage at the terminals of

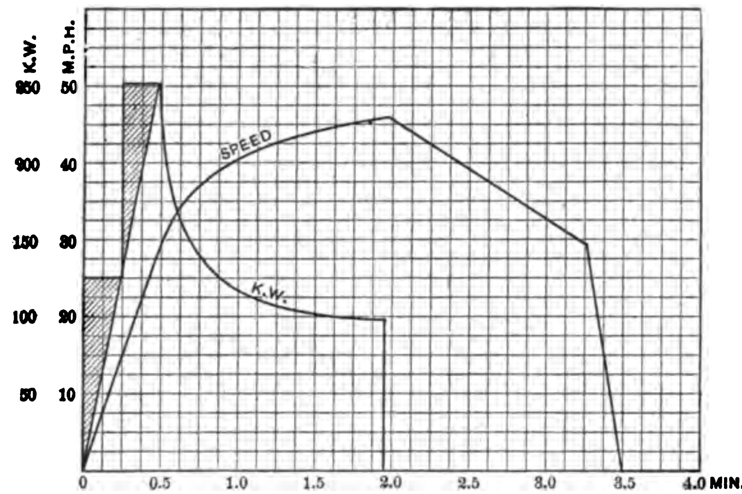


FIG. 109.—Speed Time, Power Time Curves for d. c. Operation.

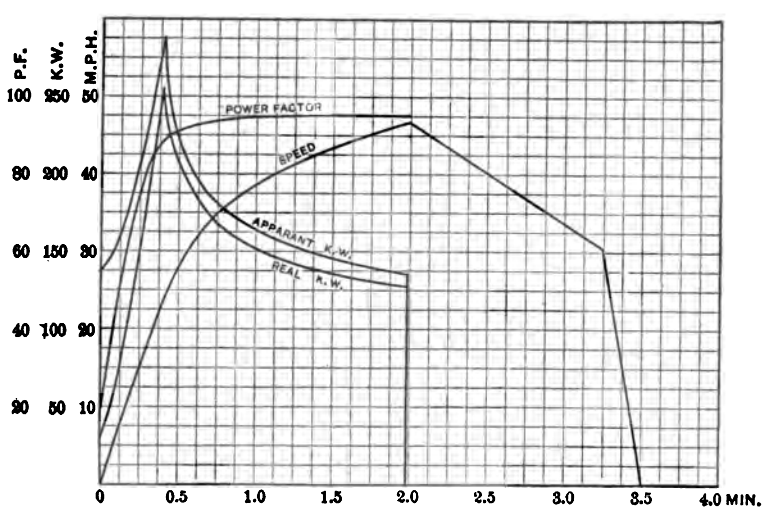


Fig. 110.—Speed Time, Power Time Curves for a. c. Operation.

the motors is regulated by connecting the motors to different taps on an anti-transformer, which is carried on the car and connected between the trolley and the ground.

For small equipments, these connections are made by means

of drum type controllers of the same general type as those used for direct current equipments. For large equipments, the Westinghouse Co. uses pneumatically operated unit switches controlled through magnet valves by a master switch and an auxiliary control circuit, to make the various connections which are required.

In traveling from one tap to the next, it is necessary that the circuit should not be broken and that the sections of the transformer winding included between adjacent taps, should

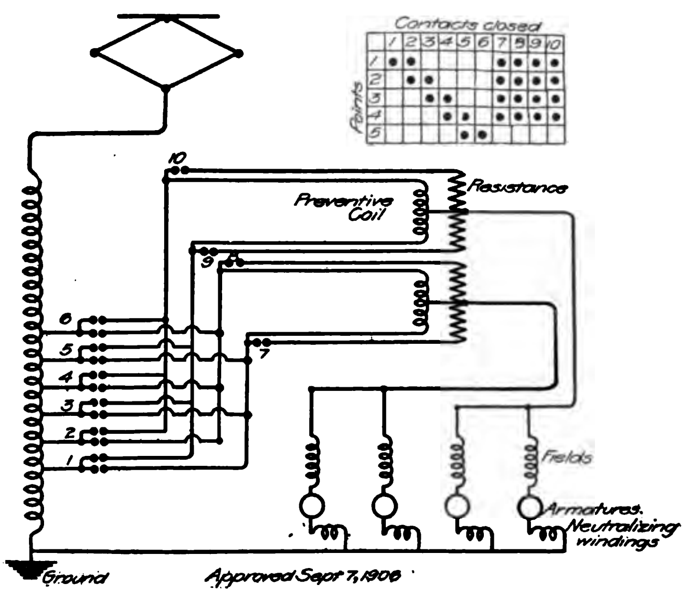


Fig. 111.—Connections for Moderate Size Westinghouse Single Phase Equipment.

not be short-circuited. These difficulties are surmounted in different ways.

The General Electric Co. cuts resistance into the circuit while making the transit from one tap to the next, thus cutting down the current set up by the e. m. f. generated in the section of the winding included between adjacent taps.

The Westinghouse Co. prevents sparking at the controller contacts when passing from one point to the next by using what they term preventive coils. These preventive coils are so connected as to offer great resistance to the local short-

circuited current and but little to the main current; they also permit the use of two taps in multiple. Fig. 111 shows the connection of these coils as arranged to use with equipments of moderate size. Small equipments employ the same arrangement except that only one preventive coil is used to supply all of the motors. Fig. 112 shows the connections used in a large equipment. In this case it will be noted that the current

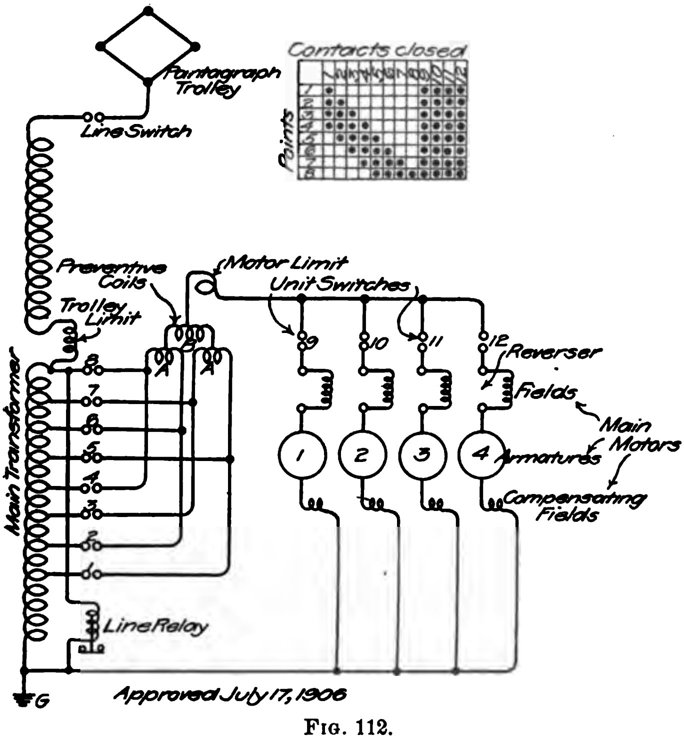


FIG. 112.

supplied to the motors is divided among four switches by an arrangement of three preventive coils. The operation of this device is shown in Fig. 113. The unit switches which are employed on large equipments are arranged in a rectangular box, as shown in Fig. 114. These switches are essentially the same that are used for the control of large direct current motors.

Both companies use the oil-cooled type of transformer to

reduce the trolley voltage to that required by the motors. Special precautions are taken to prevent the leakage of oil

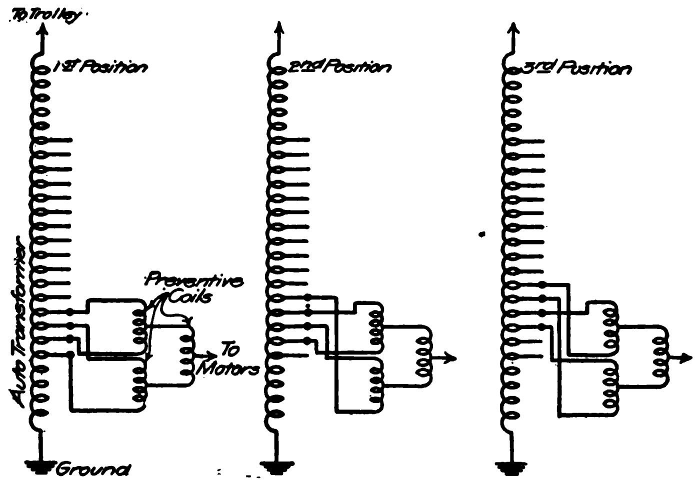


FIG. 113.—Operation of Preventive Coils.

through the bushings where the leads enter the case. Fig. 115 shows the Westinghouse transformer and Fig. 116 shows the General Electric transformer. In the latter, the stuffing

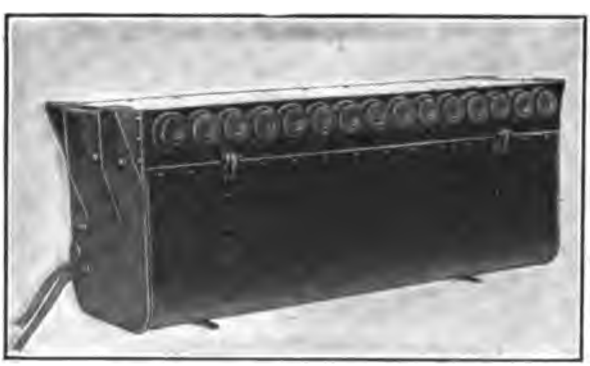


FIG. 114.—Unit Switches Used with Large Westinghouse Equipments.

boxes, which are provided to prevent the leakage of oil, are plainly seen.

Fig. 117 shows the connections of a General Electric simple

a. c. equipment. The operation is practically the same as the Westinghouse, the only difference being in the details.

A cut-out switch is used in connection with each pair of

FIG. 115.—Westinghouse Single Phase Transformer.

FIG. 116.—General Electric Single Phase Transformer.

motors to disconnect a disabled motor. As all the leads from each pair of motors run through their own cut-out switch, this is accomplished by simply turning the handle of the switch to

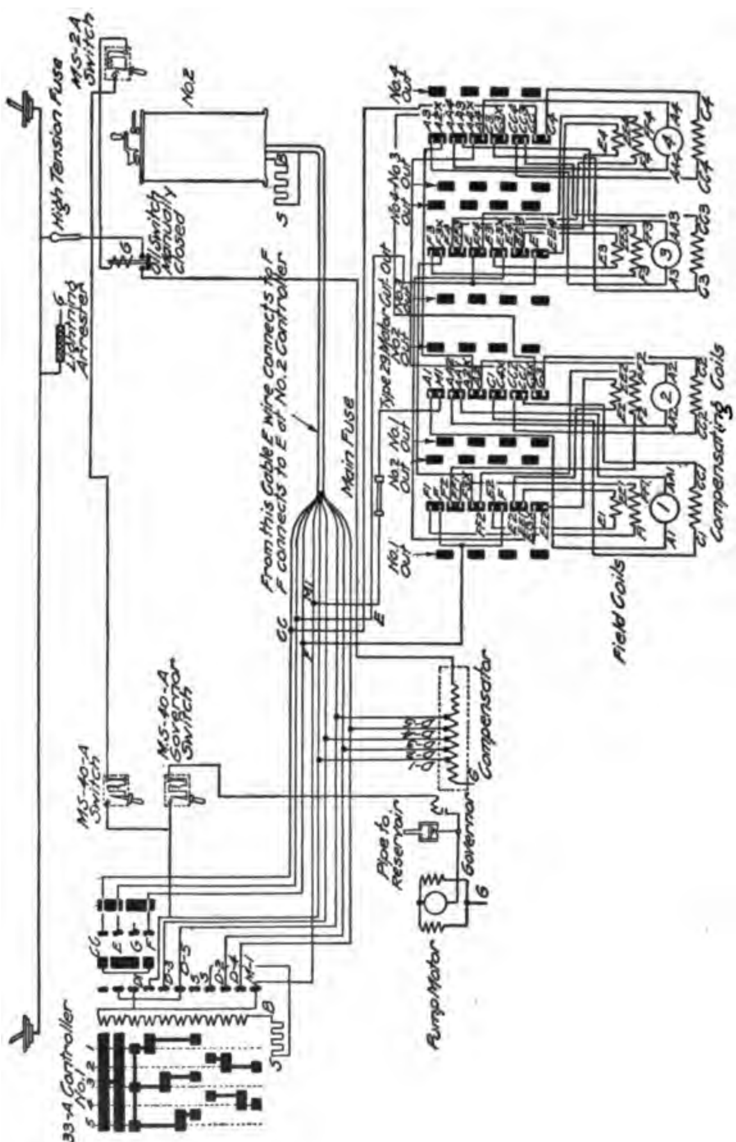


FIG. 117.—Connections of G. E. Simple a. c. Equipment.

the proper position. The oil switch in the high tension circuit (Fig. 118) is manually operated but is held closed by a coil energized from the main transformer. This switch is protected by an expulsion fuse. A single fuse of the magnetic blow-out copper ribbon type is used for protecting the motor circuit. A suitable lightning arrester protects the high tension circuit. The circuits for the air compressor motor and those governing the lighting and heating of the car are all protected by enclosed switches and fuses. All the high tension wiring is covered with suitable rubber insulation protected by a double wrapped

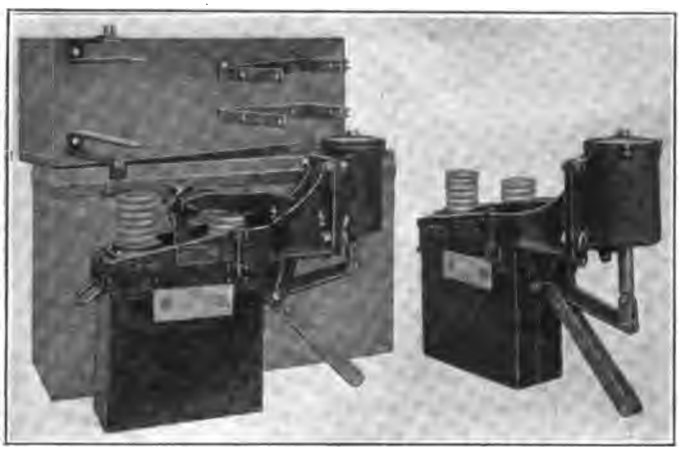


FIG. 118.—High Tension Oil Switch.

weatherproof cotton braid. It is also incased in brass piping which is carefully grounded.

To make a car operative on either alternating or direct current, additional apparatus to that used on a strictly a. c. system is required as follows: A commutating switch, main d. c. switch with its protecting fuse and lightning arrester, and also a set of rheostats for rheostatic control.

The function of the commutating switch is to make the proper change in connections required by either the a. c. or d. c. system when passing from the a. c. to the d. c. section of the line or vice versa. While running a. c. the control is by direct potential change, and d. c. it is rheostatic. The commutating switch serves to interchange the transformer taps

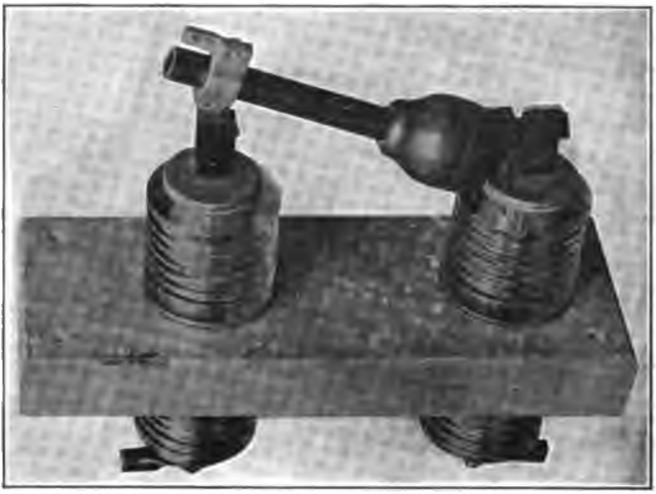


Fig. 119.—Expulsion Fuse Holder.

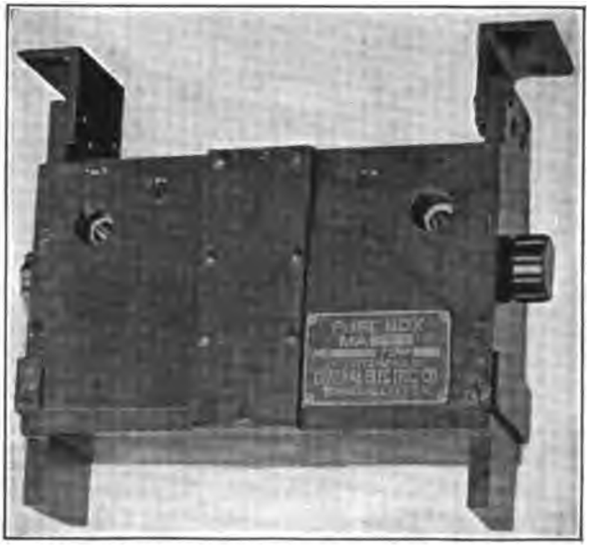


Fig. 120.—Fuse Box.

and rheostat leads as required so that the same controller is used in each case. It handles the auxiliary circuits and commutates the exciting fields of the main and compressor motors so that these fields are connected in multiple a. c. and series d. c.

Fig. 121 shows the connections of a General Electric a. c.-d. c. equipment. The controller is identical with the one used in a. c. operation. An additional feature is the set of main d. c. fingers which act as the d. c. trolley supply. The change between the d. c. and a. c. supply is handled by the commutating switch.

The main d. c. switch is manually operated like the main a. c. switch. It is held closed by a coil energized from the line supply. In construction this switch is patterned after the common electrically operated circuit breaker with the exception that its line terminal is insulated for the a. c. potential. This switch is protected by a copper ribbon fuse with magnetic blow-out.

The change from a. c. to d. c. or vice versa is made when the car passes into the dead portion between the two sections of the trolley line. Since the energizing coil on either the main a. c. or d. c. switch serves as a low voltage release, when the car enters the dead section the main switch drops out. The motorman merely changes his commutating switch by using the reverse handle of his controller and then pulls up the proper main switch.

Should the motorman close the wrong main switch, it would not be held closed by its retaining coil because its power supply is controlled by the commutating switch. During the interval that the switch is held in by the motorman and in the case where the d. c. switch is closed on the a. c. section of the line, the main trolley fingers of the controller and the trolley finger of the auxiliary circuits on the commutating switch are subjected to the high pressure. No harm would result, as these fingers are especially insulated for this condition. In the case where the a. c. switch is closed on the d. c. portion of the line the high tension expulsion fuse protects the circuit.

The motorman can at any time trip either main switch by means of a double pole single throw switch which is located in the cab.

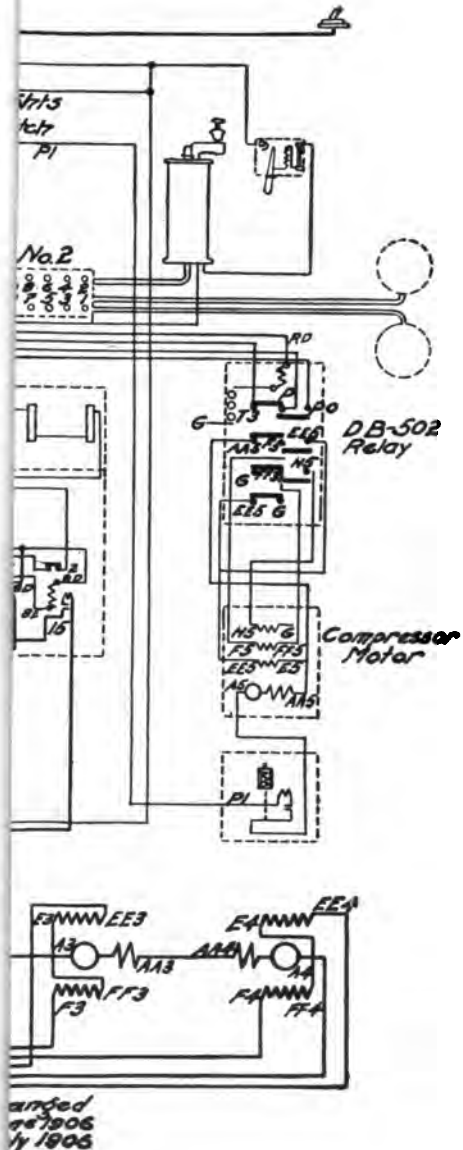

No.2
RD
G
T3
RO
D.B-502
Relay
EE5
AA5
H5
G
EE5 G
H5 G
F5 FF5
EE5 E5
A5 AA5
Compressor
Motor
P1
F3 EE3
A3 AA3
FF3
F3
E4 EE4
AA4 A4
F4 FF4
ranged
1906
ly 1906

Fig. 123 shows a schematic diagram of the connections for a Westinghouse a. c.-d. c. equipment. All of the control circuits, on their way from the master switch to the various pneumatic switches, pass through this commutating switch. When no current is passing through the auto-transformer the switch is held by a spring in a position where the control

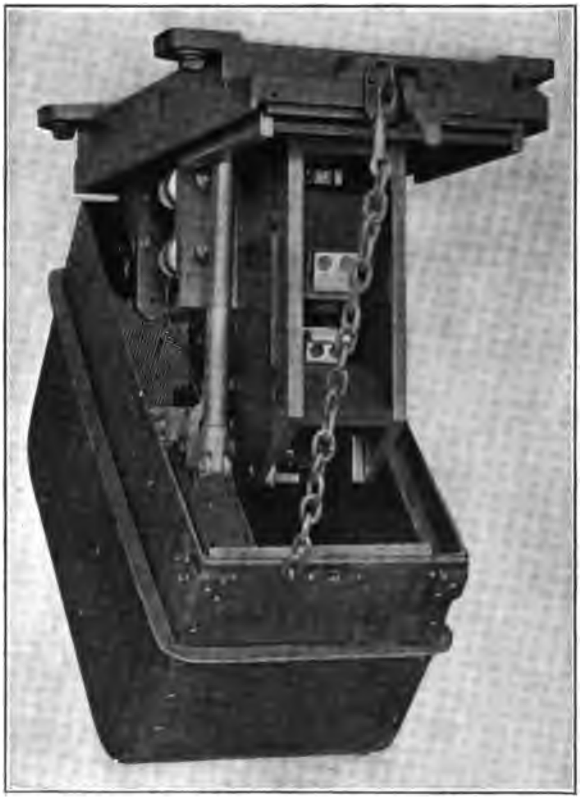


Fig. 122.—Main Switch.

circuits are so connected that by moving the handle of the master switch the proper switches for direct current operation are closed. Whenever the transformer receives alternating current, however, a magnet valve in the commutating switch is operated. This admits compressed air to a small cylinder, and throws the switch into a second position, where the con-

trol circuits are arranged for alternating current operation. It is thus only necessary for the crew of the car to see that the proper trolley is on the wire, that is, that the pantagraph trolley is in use when there is alternating current on the wire, and the wheel trolley is used when there is direct current on the wire. This matter being attended to, a movement of the master switch handle in exactly the same way, closes one

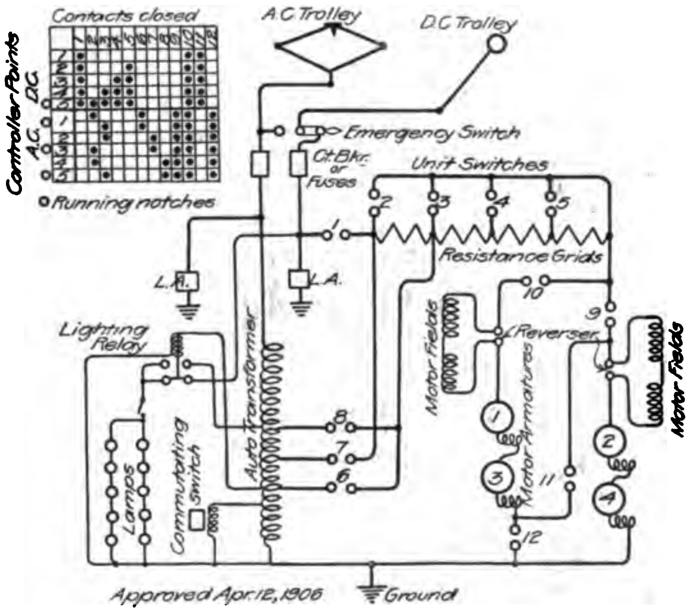


Fig. 123—Diagram of Connections for Westinghouse a. c. - d. c. Equipment.

set of switches in one case and another set of switches in the other case, according to the current employed.

Where equipments of moderate size are used on both alternating and direct current, a hand operated drum type controller is employed, making essentially the same connections which are made by the unit switches in the case of large equipments. Where this drum type controller is employed, however, no commutating switch is used, but the operating handle is placed on the shaft of one drum when the car is used on direct current, and on the shaft of another drum when alternating current is used.

The current may be collected by means of standard trolley wheels, poles and bases applicable for high speeds, or, when desired, a sliding or rolling contact collector of the pantagraph

Fig. 124.—Pneumatically Operated Pantagraph Trolley, Raised.

Fig. 125.—Pneumatically Operated Pantagraph Trolley, Lowered.

or bow type may be employed. Figs. 124 and 125 show views of the pneumatically operated Westinghouse pantagraph trolley, which is used for operation on 6600 volts or less. For higher voltages, larger insulators are used. This trolley is

normally held up against the wire, as shown in Fig. 124, by means of springs. If it is desired to lower the trolley, compressed air from the brake system is admitted to the cylinder and the trolley is thus forced down to the position shown in Fig. 125.

There has been developed suitable apparatus capable of controlling both single cars and trains equipped with single phase motors, when operating on lines supplied wholly with alternating current, or with alternating current on one position of the line and direct current on another.

In general the wholly alternating and alternating direct current multiple unit systems of control are similar to that control which has been for some time so successfully used in direct current operation. The differences are of a simple nature and all of the advantages of the older type of construction are retained.

The system provides for the control of motor cars when operated singly or in trains of several cars, being adapted to either single cars of a capacity too great for a cylinder controller or to all types of cars which may be possibly operated in a train. The circuits are arranged in such a manner that when a number of cars are coupled together, the motors may all be operated collectively and simultaneously from either end of any car. The cars composing the train may be coupled in any desired relation with each other, and every motor will at all times perform its equal share of the work.

Fig. 126 shows the connections of the General Electric multiple unit control adapted to a. c. operation only. The essential parts of the equipment are: Master controller, train cable and couplers, contactors and box, compensator, grid rheostats, trolleys, motor cut-out switches and the necessary protecting devices.

The master controller is of the standard type, being similar to the direct current master controller used in straight d. c. operation. It is considerably smaller than the ordinary street car controller, but is similar in appearance and operation. It is furnished with an automatic release, which cuts off the current from the entire train, should the motorman remove his hand from the handle. The function of the master controller is to take care of the control circuit only and, there-

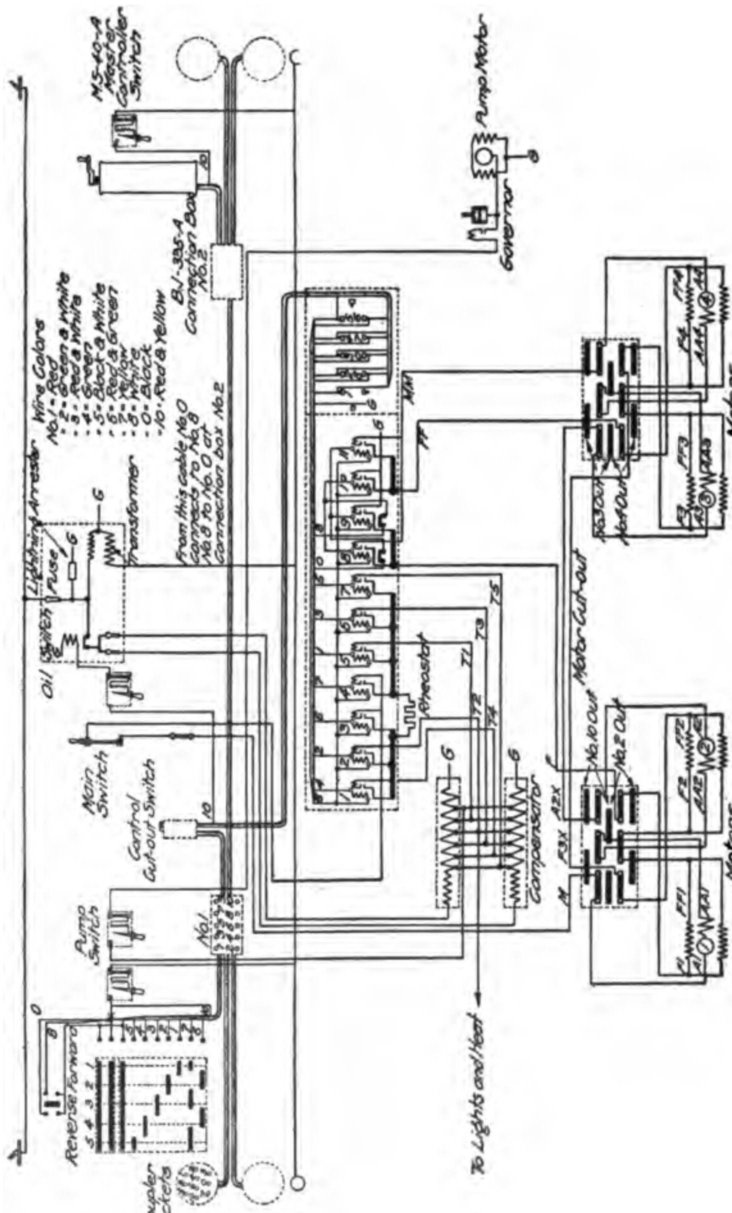


FIG. 126.—Connections of G. E. Multiple Unit a. c. Control.

fore, it only deals with the current which energizes the coils of the contactors. It is never called upon to handle heavy currents, all the apparatus dealing with heavy current or high voltage being placed either under the car or in a specially protected compartment. Each contactor (Fig. 127) consists of an electrically operated switch, depending on a solenoid for its action. The magnetic circuit is composed of laminated iron. Each contactor is provided with a moulded insulation arc chute.

The contactors are assembled in a box with an iron framework and sheet-iron cover. The box is designed for use in conjunction with brass conduits having suitable entrances for the main cables and a connection box for the control cables.

The transformer, motor cut-out switches, rheostat, trolley, and switches for the secondary circuits are identical with those used on a hand control system.

The protective devices, including an electrically operated oil switch with its protecting expulsion fuse and lightning arrester, together with a small step down transformer used to supply current to the control circuit and retaining coil of the oil switch, are collected in a high tension compartment in order to isolate them.

During operation the car is controlled as follows: On the first point of the master controller the motors are connected to a compensator tap giving approximately half voltage. After this point acceleration is obtained by cutting in more sections of the compensator winding until on the last tap the motors are connected to the full working voltage tap. A cast grid rheostat is cut into circuit during the instant of changing the motor connections from each compensator tap to the succeeding tap. This permits of an uninterrupted current supply to the motors without short-circuiting the various sections of the compensator winding.

The motors are operated all four in series and are reversed by a change of field connections. This last operation is performed by a set of four contactors located in the contactor box.

To adapt the multiple unit system for both alternating and direct current operation, apparatus has been developed which

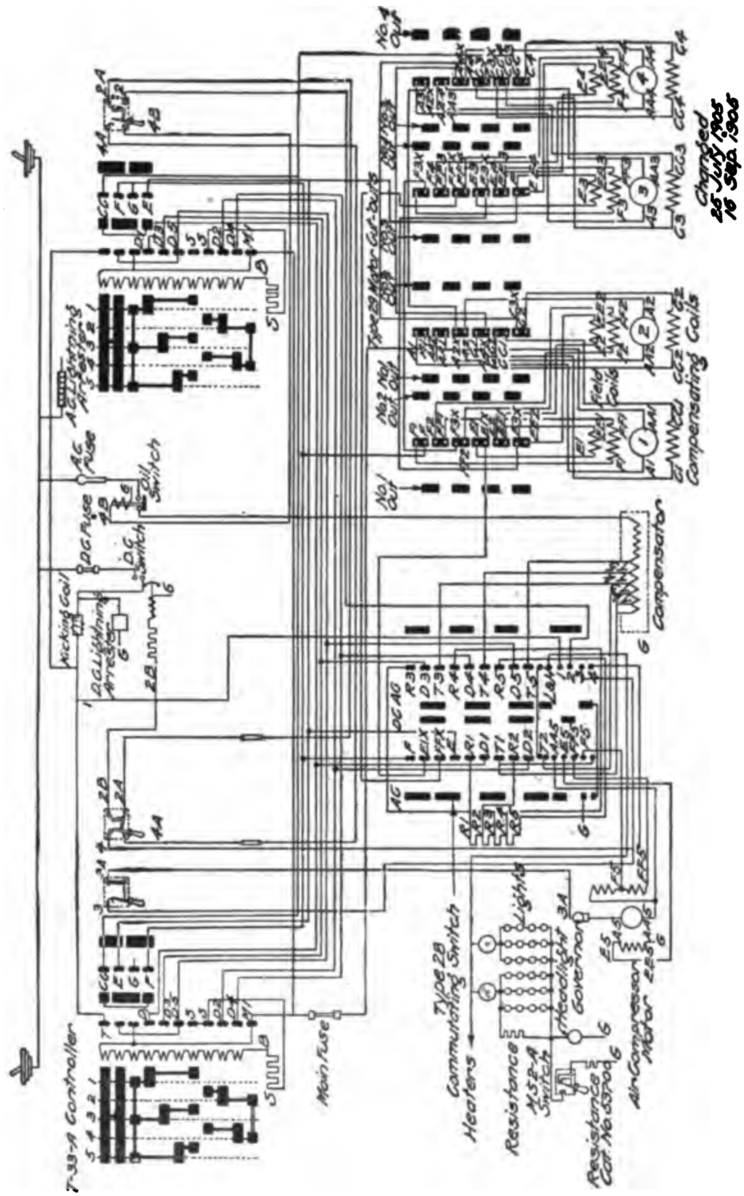


Fig. 127.—Connections of G. E. Multiple Unit a. c. - d. c. Control.

renders every operation, peculiar to each system, entirely automatic and independent of action by the motorman.

Fig. 128 shows the connections of the General Electric multiple unit control for both a. c. and d. c. operation. The apparatus for each equipment consists essentially of master controllers, train cable and couplers, two sets of contactors with a box for each, compensator, set of rheostats, commutating switch, reverser, trolleys, protective apparatus and devices for making all changes automatic.

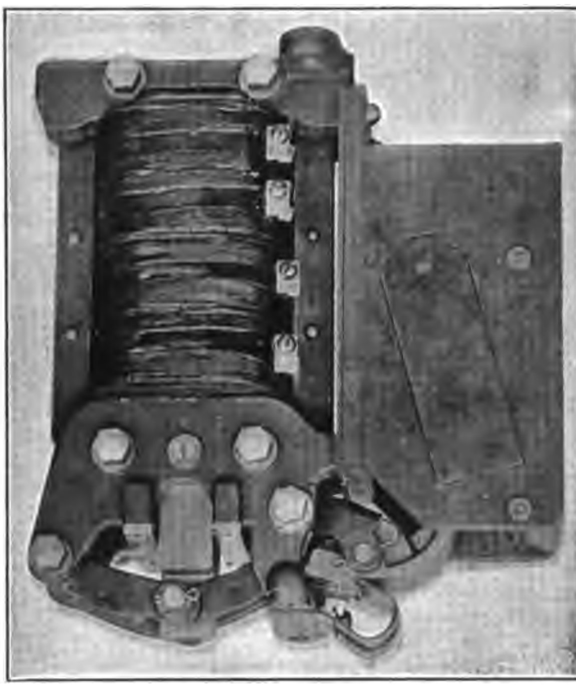


FIG. 128.—Contactor Used in G. E. Multiple Unit Control.

The type of contactor used is adapted to operate on either alternating or direct current circuits. It is provided with a powerful magnetic blow-out similar to that used on standard d. c. contactors.

Equipments have been developed for operating with all four motors connected in series, and with a series parallel combination of motors. The motors during a. c. running are per-

manently in series. While running d. c. they are brought partly up to speed in series, then thrown into pairs in parallel.

A standard type of reverser, modified to take an a. c.-d. c. operating coil, is used to change the direction of rotation of the motors.

The commutating switch resembles the reverser both in size and operation. The finger and segment development, only, being different. The function of the commutating switch is to commutate the motor fields, control the trolley supply to the auxiliary circuits, and in conjunction with a series of contactors to regulate the motor connections; i. e. when the car is on a. c. the commutating switch connects the motors in series; when the car is on d. c. the contactors are used to make the series parallel combination of the pairs of motors.

Potential and rheostatic control is used while operating a. c. and d. c. respectively.

In order to make entirely automatic the changes necessary when passing from the alternating current to the direct current sections of the line or vice versa, the following arrangement of apparatus is used: Primarily everything depends upon which main switch is closed; for immediately the proper trolley supply is delivered, the necessary connections are made by the governing apparatus.

The secondary winding of a small transformer is in series with the retaining coil of the oil switch while its primary winding is in series with the operating coil of the main d. c. switch. A tap from the trolley is connected to ground through this last series. When the power supply is d. c. the current flows through the transformer primary and d. c. operating coil of main d. c. switch; the latter becoming operative, the circuit is closed. Meanwhile the oil switch is inoperative as there is no transformer action.

In the case where the power supply is a. c. the oil switch is closed, its coil being energized from the transformer. The d. c. coil is inoperative, owing principally to the impedance of the circuit.

Both the high tension and direct current circuits are protected by fuses and lightning arresters.

TRUCKS

The evolution of the street car truck from that originally used under horse cars, to the modern motor trucks adapted to the different classes of service, has been very rapid. The history of this transformation is of little interest, so it only remains to describe and illustrate those trucks which are in common use, and may be said to have become standard. Though there are a number of different makes of trucks in general use, they conform more or less closely in general design to these mentioned and it would not be advisable to enter into a description of them all.

Trucks have become divided into certain definite classes made necessary by the different uses to which they are put. They may be called the single truck (Fig. 129) adapted for one, or two, inside hung motors. The maximum traction double truck (Fig. 130) adapted for one motor each, either inside or outside hung. These trucks carry over 75 per cent. of the weight of the car body on the motor driven axles, and thus are able to utilize the weight for the tractive effort. They are much used in city service where there are few grades and moderate speed is required. The short wheel base double trucks (Fig. 131) usually equipped with two motors each, and outside hung, are widely used in city and suburban as well as light interurban service. This provides a four-motor car able to run 30 or 35 miles per hour in the open country, and which can also take the sharpest curves in the city without difficulty. Heavier trucks for high speed interurban service generally take the form of an all steel M. C. B. truck (Fig. 132) with inside hung motors, and a wheel base of from 6 feet to 7 feet. Fig. 134 shows a heavy interurban truck made by the Baldwin Locomotive Works.

The desirable features to be looked for in any truck are strength and rigidity. By the latter is meant stiffness of the frame with the ability to keep it in square. A truck which gets out of square on account of an accident, or because the strains have made bolted joints give, is sometimes difficult to bring back into position and hold there. It throws the axles out of parallelism, and this introduces much friction, especially in rounding curves. All manufacturers have braced

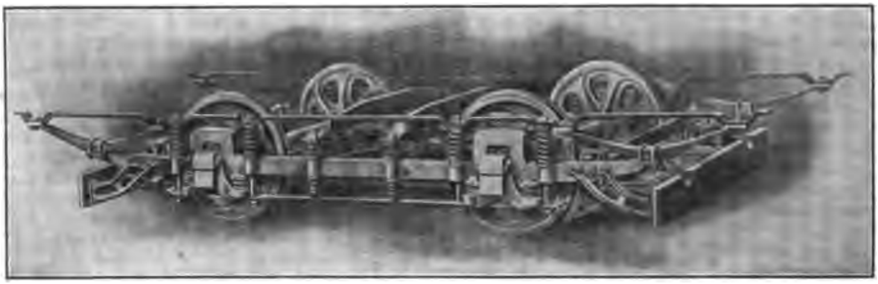


FIG. 129.—Single Truck Inside Hung Motors.

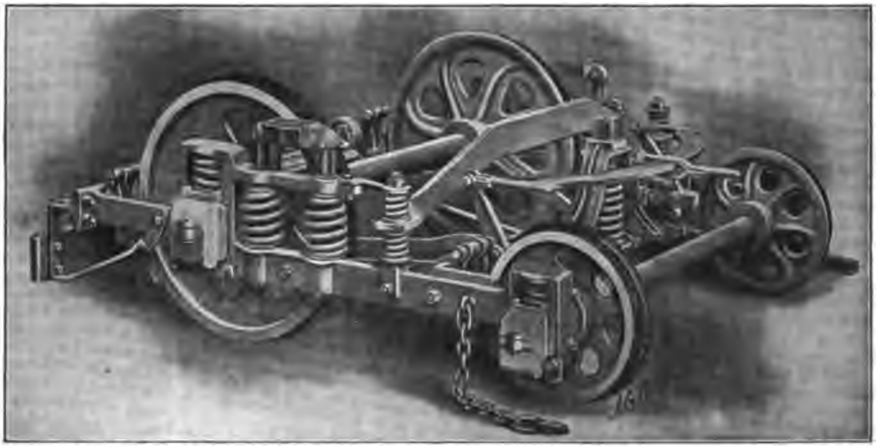


FIG. 130.—Maximum Traction Truck.

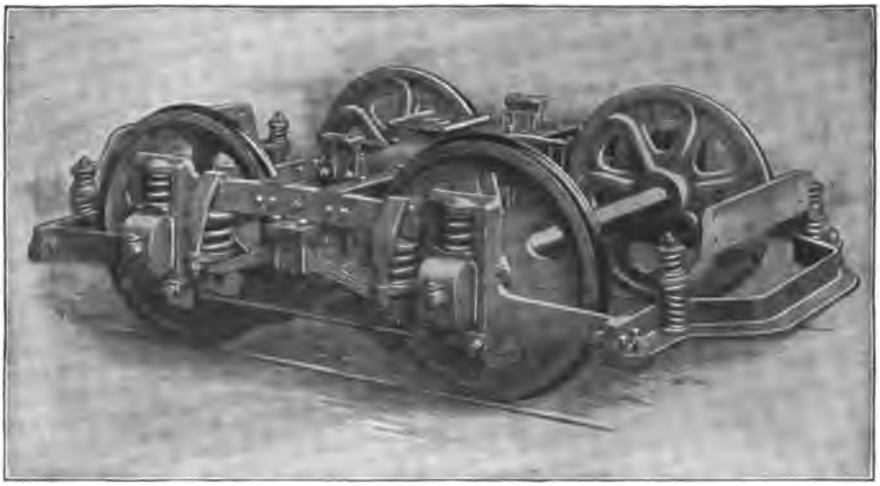


FIG. 131.—Brill Truck with Short Wheel Base and Outside Hung Motor.

and stayed their truck frames with the intention of holding them square, as much as it is possible to do so. The side frames may be built up, or forged solid, or cast steel, and they have the two end frames, and the center transom, to hold them in square. Much depends on the design of the connection between these end frames and transom, with the side frames, for these are the weak points.

The M. C. B. type of truck is that used by all steam roads under passenger coaches principally, and usually has a frame of wood. When used as a motor truck it is built entirely of steel. The weight of the car body is carried by the bolster at the center plate and side bearings, though the latter are so adjusted as to carry no weight when the car stands level. The bolster transfers the weight to the spring plank through the elliptic springs placed between them, and the spring plank is hung to the transom by the four swing links, two at each end. The object of these links, which are placed at a slight angle to the vertical, the lower ends being further out than the upper, is to absorb the shock due to side lurches of the car, especially at curves. Sufficient end play is allowed for the resulting side motion of the bolster. The weight having been transferred to the frame, it is then passed on through the equalizer springs to the equalizer bars, which in turn convey it to the journal boxes and axles. This style of truck is the result of years of development, and while there are slight variations in construction the general principle of the design is the same in all.

One of the important points sought for in any truck is that it must be easy riding. On a smooth track almost all trucks will run satisfactorily, but to so arrange and design the springs that the truck imparts an easy motion to the car body when running over a rough track is a problem difficult to solve. The M. C. B. truck is generally satisfactory in this respect if the strength or stiffness of the springs is properly proportioned for the average load to be carried.

A type of truck which is widely used but can hardly be called a variation of the M. C. B. type, as it involves a different principle is the Brill 27G (Fig. 131) and 27E. In the former the bolster is carried directly on the equalizers, there being no spring plank. The equalizers themselves consist of semi-elliptic springs instead of bars. There are no swing links as

in the M. C. B. truck, but the ends of these equalizers are carried by spring links hung on the side frames and containing equalizer springs within them. The side frames are carried

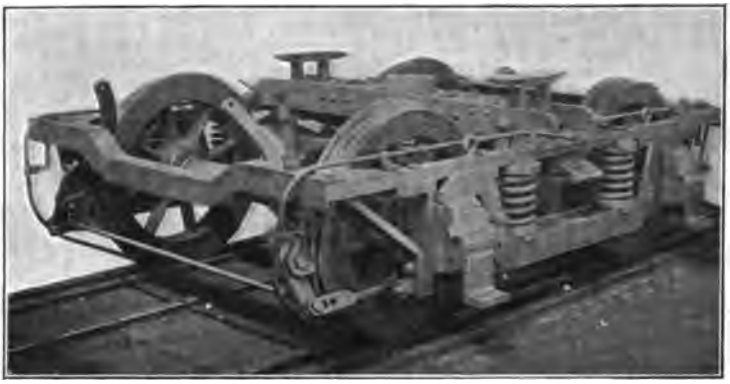


FIG. 132.—M. C. B. Truck with Inside Hung Motor.

by journal box springs. The effect of this combination of springs is to place the different groups in series. In other words, the blow from the car wheel has to pass first through

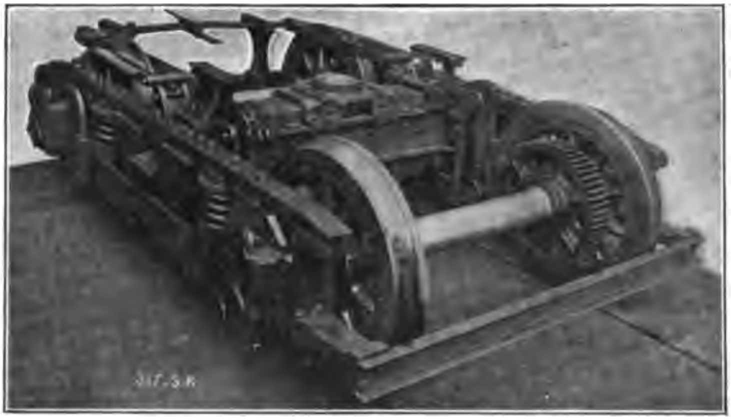


FIG. 134.—Baldwin Heavy Interurban Truck.

the journal box springs, thence through the frame to the spring links, and thence through the equalizer springs to the bolster and car body, and by that time the violence of the blow is greatly reduced. The side motion of the bolster is provided for

by the swinging spring links on the side frames. The 27E (Figs. 135 and 136) truck is similar to the above except that the equalizers themselves are bars, a spring plank being rigidly

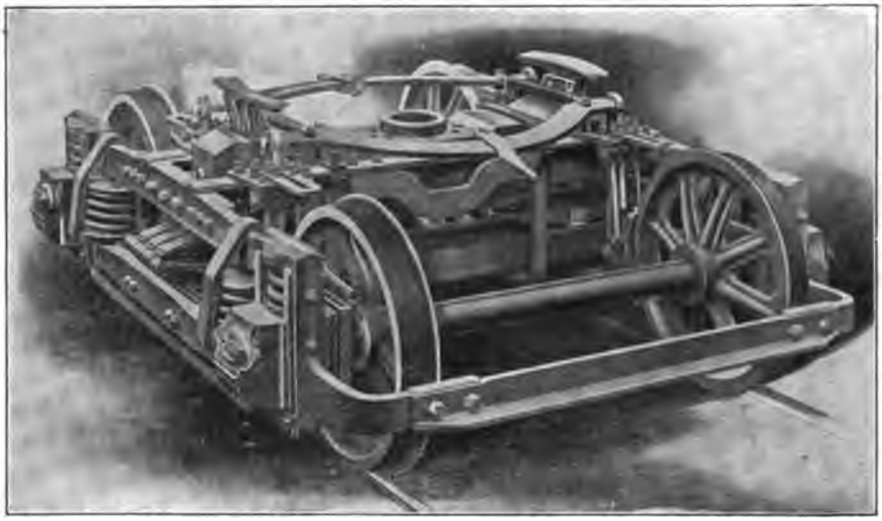


FIG. 135.—Brill Truck No. 27-E-2.

FIG. 136.—Brill Truck No. 27-E-3.

attached to them, and their ends supported by the spring links. The bolster is supported by elliptic springs on the spring plank.

Considerable might be written regarding the advantages and disadvantages of built up, cast steel, or solid forged frames. The former was the original method and at one time very care-

less means were employed in their construction. Rough surfaces were bolted together by bolts anywhere from $\frac{1}{32}$ to $\frac{1}{16}$ inch smaller than the hole, and the latter was punched where possible instead of drilled. The result was, in spite of lock washers and jam nuts the joints soon worked loose and the truck fell out of square. In the modern built up truck, however, very different methods of construction are followed. Surfaces in contact are planed or milled to a fit, holes are carefully drilled and then reamed slightly taper. Machined bolts are used of proper size to form a driving fit in these holes. Such work is expensive, but it produces a built up truck of which little or no complaint is ever heard. Cast steel frames can scarcely be said to be uniformly successful up to the present time. While many of them are in use and giving no cause for complaint, others have cracked and failed due usually to flaws in the casting impossible to detect. The element of chance is an important factor here. Solid forged frames have many points to recommend them. While it requires an expensive plant to forge them, they are generally free from defects, and the number of bolted joints is reduced to a very few. They are cheaper than good built up frames, but more expensive than cast steel. Cast steel bolsters are used to a considerable extent, replacing those of the built up type, and seem to give satisfactory results. Such bolsters are widely used under steam road freight cars for both body and trucks.

Brakes

A brake is a very essential part of the equipment of any power driven vehicle, in fact it may be said to be almost as important as the motor, for one would be of little use without the other. On the ability of a motorman, or locomotive runner, to stop a car or train within a certain distance, which is learned by experience, depends not only the safety of the lives of passengers, but the prevention of wrecks involving much loss of property. The highest skill in braking may be the stopping of a heavy freight train at the foot of a down grade where there is a water tank, with the spout exactly over the opening in the engine tender. The practiced motorman or engineer knows the danger zone ahead, within which he cannot expect to stop, whether he has only the ordinary hand brake, or the high speed

air brake. An idea of what this distance is can be gathered from some of the data on the shortest stops on record with high speed trains. At a speed of 50 miles per hour, the stopping distance from the time the brake was applied was 602 feet, at 60 miles per hour it was 982 feet and at 70 miles per hour it required 1,334 feet. When it is remembered that these are among the shortest stops on record, and that most trains require 20 to 30 per cent. greater distance, it can be seen how helpless is the engineer or motorman running at the above speeds within these distances, and at 70 miles per hour it is useless to watch for signals or obstructions nearer than ¼ of a mile.

There is very little, if any difference, in the length of a stop of a steam or electric driven train provided each car has the proper braking power applied to it. Neither does the length and weight of the train have much effect on the stop provided each car is properly braked. In ordinary freight cars, the difference in their weight when light and loaded is so great, and both empty and loaded cars are liable to be included in the same train, that it has not been found advisable to adjust the braking power applied to the wheels to give over 70 per cent. of the light weight of the car.

In a heavily loaded car consequently but 40 or 50 per cent. of the total weight is available. In regard to steam passenger coaches, and locomotive drivers, a braking force of 90 per cent. of the total weight is the usual practice. Ordinary city and suburban electric cars usually employ about 90 per cent. also. On high speed interurban cars a phenomenon was encountered in the inertia of the armatures, which opposed the brake, rendering higher braking pressure necessary to overcome it. At 60 miles per hour it is possible to apply a pressure of 125 per cent. of the total weight without sliding the wheels, but as the speed decreases the armature inertia is also reduced and the braking pressure must be partially released in order to prevent wheel-slip. Theoretically a wheel will slip when the brake pressure equals the weight carried by it, but this flywheel effect of the armatures has no relation to the coefficient of traction, and can only be overcome by increased pressure on the brake.

In the past it has always been a difficult problem to make the results obtained in a brake test agree with the theory of fric-

tion, due to the extremely variable conditions under which different tests are necessarily made. It has been equally difficult to make a series of tests approach a reasonable agreement with each other. At present the causes of these variable results are better understood and a fairly accurate knowledge of what is required is now possessed by those interested. Some curious facts have been found; one is, with a constant brake shoe pressure, the friction between the shoe and the wheel at a speed of 60 miles per hour is only one-half that when the speed is 20 miles per hour. In other words, to stop a train in the shortest distance, without slipping wheels, the brake shoe pressure at highest speed must be nearly equal to the weight of the train, and must be gradually reduced as the speed decreases. Another fact is, that a long continued application of the brake often results in a decrease in brake shoe friction. Generally speaking, ordinary applications of the brake must be limited by the comfort of the passengers, and the "emergency application," so called, is only used in case of danger. It has been found, however, that an application of the brake producing a given rate of retardation at one speed, will not cause any greater danger or discomfort to the passengers if applied at any other speed, provided the same rate of retardation is obtained. The perfect stop is known as the uniformly decelerated stop, and is one in which a pendulum will take a position when the brake is first applied and hold it until just before the stop, when it will gradually assume the perpendicular. It is, of course, practically impossible to vary the braking pressure in exactly the manner to produce this stop, for while theoretically the variation should be a regular reduction in pressure, practically the varying conditions of friction would necessitate an irregular reduction.

It would be of little interest here to discuss the many different types of brakes which have been tried and discarded, or those which are in use to a limited extent. Attention will be confined then to the two classes—hand brakes and air brakes—both of which seem to be here to stay as regards electric motor cars. That air brakes have first occupied the field among power brakes on electric cars is undoubtedly due to their previous development by the steam roads, but it would seem that such a source of power as the electric current on the

car could have been utilized directly on the brake system without the conversion into compressed air. While several methods of doing this are in use, their development has been so slow that it is doubtful if they can ever supersede the former method. The magnetic electric brake, in which two discs are brought into contact, one stationary and the other moving with the axle, has not proved a success on account of overloading the motors. The solenoid electric brake has been tried with a fair degree of success, and also has the magnetic track brake.

What is known as the straight air brake, manufactured principally by two firms, is in use to-day on the majority of heavy double truck motor cars. There is no essential difference between the two types. The motor driven compressor, the automatic governor or controller, and the motorman's brake valve, differ slightly in mechanical and electrical details, but the remainder of the brake mechanism is practically identical. Both accomplish the same results in the same manner. The air compressor supplies air to the reservoir at a pressure usually from 60 to 75 pounds per square inch, dependent upon the adjustment of the governor. An iron pipe, ½ inch inside diameter, connects the motorman's operating valves at each end, with the reservoir, and another connects the brake cylinder with both valves. These valves are three-way, and a movement of the handle in one direction allows the air from the reservoir to flow through the valve into the brake cylinder pipe, or train pipe, as it is called, and passes through this to the brake cylinder, thus applying the brake. A movement of the handle in the other direction shuts off the air from the reservoir, and allows the air which has been used in the brake cylinder to escape to the atmosphere through the valve. This straight air brake is exceedingly simple, and any man of average intelligence can easily understand it.

Storage air brakes, which are used to a considerable extent in a few large cities, differ from the above only in the manner of obtaining the compressed air. In place of the independent motor compressor, air is compressed by large machines located at convenient points, and the cars carry extra reservoirs, usually two in number, which are charged at these stations with air at 300 pounds per square inch. A reducing valve is placed between these reservoirs and the brake reservoir, which sup-

plies the latter with air at from 60 to 70 pounds. This operates the brakes in the same manner as when the car carries its own compressor. (See Fig. 137.) The system has some advantages as regards cost of maintenance, and is especially suited to large systems in cities.

When a car is equipped with air brakes its weight must be known, and the leverage is usually adjusted to give a brake shoe pressure of about 90 per cent. of the weight, with 60 pounds pressure of air in the brake cylinder, first selecting the proper size of cylinder. After the equipment is complete the car is tried on a dry rail, at medium speed, and the brake given the emergency application. This means that the whole pressure of the reservoir is suddenly admitted to the cylinder by opening the valve wide. If this test skids the wheels the pressure is lowered slightly, by adjusting the governor, until it is not possible to do so. At very low speeds and on slippery rails it will slip the wheels unless the rails are well sanded at the same time. The object of the air brake engineer is not to place sufficient power in the brake to enable the motorman to flatten wheels on a dry track, but to give him just enough power to obtain the whole efficiency of the brake. On wet and slippery track a motorman must use care and judgment with the air brake, just as he does with the hand brake. When a road is newly equipped with air brakes, some flat wheels must be expected, until the men are thoroughly acquainted with the brake; afterward there should be no more trouble of this nature than there was with the hand brake.

It might be well to state here that there is no better adjunct to an emergency stop, on a slippery rail, than dry sand. It increases the stopping power of the car possibly 50 per cent., and may be the means of saving lives and property. Too little attention has been given to the use of sand in braking, but the fact is in these days of heavy high speed cars, it is just as important in stopping as it is in starting when needed. Four-motor cars seldom need it in starting, even on a grade, unless pulling a heavy trailer, yet many manufacturers of sand boxes and their appurtenances seem to assume that their devices are only to be used in starting. One manufacturer was asked if his apparatus would sand the rails on a curve. His reply was: "You don't sand curves, you grease them." It would seem if

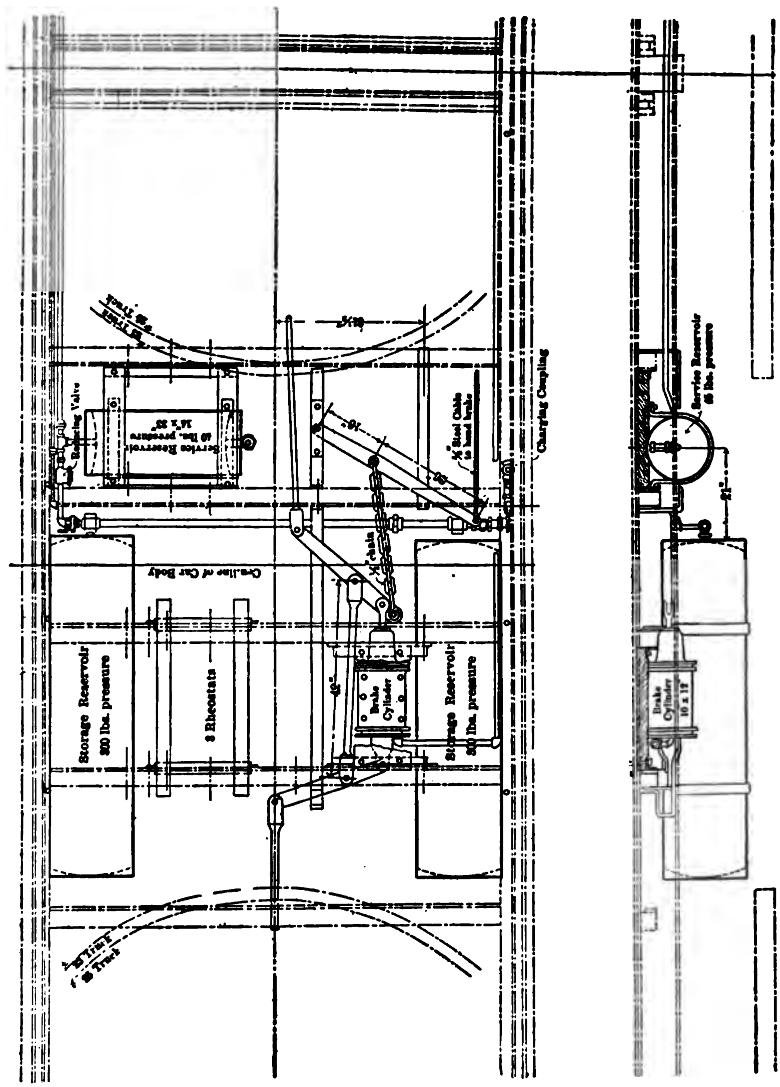


FIG. 187.—Storage System of Air Brake.

a motorman with a fast interurban car were approaching an ordinary curve, either on down grade, or level track with danger ahead, and the brake in emergency, he would prefer to sand that curve rather than grease it. Of course in the short radius curves of the cities where low speeds are compulsory, greasing the curves is a necessity. It all depends on the conditions.

One other important point in the brake equipment of a modern car is the condition of the hand brake. On many roads this subject is given little or no attention after air brakes are installed. Far too often we find the motorman stopping by reversing when the air brake becomes disabled. On inquiry we are informed the hand brake is "no good." This condition of affairs should never be allowed to exist, and usually it is the fault of the man in charge of the equipment. On some roads rules are issued instructing the motormen to always use the hand brake at the last stop of a trip, or on a certain heavy grade during the run. In this way the hand brake is used a number of times each day and is consequently kept in good order.

In many cases when a car is equipped with air brakes, the hand brake rigging is attached to the air brake by a short chain, so that the regular system of air brake levers and rods is operated when the hand brake is used. This is not good practice as regards safety, for any derangement of the air brake rigging then puts the hand brake out of action as well. The better method is to have the hand brake rigging independent of the other, using separate brake rods. This brings the independence of the two systems back to the truck levers, which with the brake beams and shoes are still common to both. On certain roads, with very steep grades, it is considered advisable to carry this independence of the two systems all the way, so that any accident whatever to one will not interfere with the other. This is the system of double brakes, where each wheel has a shoe on each side of it. The inside shoes are controlled by one brake and the outside shoes by the other. It is perhaps a little complicated, but the object is gained when the hand brake is well maintained.

In air brake systems the distance between the shoes and wheels, when the brake is released, is governed by the piston travel in the brake cylinder, or vice versa. Ordinarily the

standing piston travel can be adjusted as low as 4 inches. The running travel, that is when the car is under headway, will then be 5 or 5½ inches. This is due to the flexibility of the system, the jarring of the car allowing all slack in connections to be taken up. The piston travel should be taken up when the wear of the shoes allows it to reach 8 inches when running, for it then requires nearly double the amount of air to operate the brake. On all roads using air brakes, piston travel should be given the strictest attention by inspectors, for it is the key-note to the successful operation of the brake.

Piston travel should invariably be adjusted by means of the turn-buckles in the bottom rod of the truck brake, and never by turn-buckles in the air brake rods, or in the cylinder lever tie rod. If the latter rods are made the proper length at first, they never need adjusting, and it is a mistake to place turn-buckles in them.

The air pressure gauge should be placed where the motorman can see it without turning his head, and he should be carefully instructed that the efficiency of his brake depends on the reading of the gauge. The amount of energy consumed by the air compressor on the car is remarkably small when compared with the energy required to drive the car, being in some cases probably about 3 per cent. of it, or about 30 per cent. of the current required to light the car. One series of tests in regular service showed .064 kw.-hour per car mile, as the average amount of energy consumed by the air compressor. This figure being a fair average does not show the great fluctuations to which it is liable on different cars, and under various conditions as regards the use of the air, leaking pipes, etc., but it is fairly sure to seldom rise above that required by the lamps. Statements have been made to the effect that the total energy consumption of an air braked car will be no more than it was on the same car, and in the same service, before it was equipped with air brakes. Probably it is possible in special cases for this to be true. If we consider a city service and a certain schedule, the hand braked car has to be run under close control, and to do so the motorman has all the slack of the hand brake taken up, and the shoes touching the wheels, so that he may make a quick stop. In addition he runs very slowly on the first controller steps, and drifts but little. On the other hand, the air braked

car is always running at a slightly higher speed under similar circumstances, with the brake in full release, and the controller frequently in the series position, or shut off and the car drifting with no current. The motorman is fully aware that he can easily make schedule time, and can stop suddenly at any moment within a much shorter danger zone than before. Under such circumstances, and with other conditions favorable, it is possible that occasionally the air braked car can run with about the same total energy consumption as the same car using only hand brakes, but such cases are rare.

The cost of maintaining an air brake equipment varies in about the same manner as the cost of maintaining the motive power equipment of the car. It depends entirely upon the existing conditions on the different roads. These conditions mean not only the physical characteristics of the road as regards grades, etc., but also on the kind of care and inspection the equipment receives from those immediately in charge. In this last condition lies the whole secret of the cost of maintenance. Rigid daily inspection of the air brake equipment is more necessary than the inspection of the motors and controllers. No better example can be followed than the attention given air brakes by steam railroads. Every time a valve, or brake cylinder, is taken apart and cleaned, the date of such cleaning is stenciled on the apparatus, and if the necessary work is not done at stated intervals, the attention of the proper man is called to these dates. Every steam road has ordered that the engineer and car inspectors shall test the working of the air brake on every train after it has been made up, and is standing in a terminal station, before starting on its run. Some roads require that there shall be an additional running test within the first thousand feet after starting, in order to be sure the brake is in working order. Is it not just as important to adopt these methods on our interurban roads? In the majority of cases, the failure of an air brake on an electric car is due to such trifles as a worn-out carbon brush in the motor compressor; to some disarrangement of the connections to the automatic governor; or to a blown fuse: troubles which can be repaired in less than five minutes, and are nearly always due to careless inspection, or more often, to no inspection at all. A safety or relief valve is essential. On some roads the air whistles

are very freely used, as regards the amount of air consumed. It is seldom appreciated that two or three short blasts of the whistle require as much air as an ordinary application of the brake. All this increases the time during which the compressor must run, and indirectly the cost of maintenance. The result is that the cost of maintenance on different roads varies to an astonishing degree. One large system, using many cars equipped with air brakes which were well taken care of, kept a careful record of repairs, and found that it cost, in labor and material, 30 cents per month, per car, or 1 cent per day. This is a fair average record, but does not include brake shoes.

Automatic air brakes are seldom used on street or interurban railways, owing chiefly to the fact that cars are not generally run in trains. On elevated roads, however, where trains of 3 to 8 cars are common they are invariably used. The brake is exactly the same as that used on steam roads except that the air compressor is driven by electricity instead of steam.

A combination straight and automatic air brake system is rapidly coming into use, where electric cars are operated in trains. In this system, the application of the brake is automatic while the release is similar to the straight air system.

Controllers

The control of the speed of any power driven vehicle has long been the subject of deep study on the part of engineers and inventors. As far as efficiency of operation and lack of complication is concerned the steam locomotive, by variation of the throttle opening and cut-off, probably has the best of it at present. The gas engine driven automobile undoubtedly occupies a position at the other end of the list, for it has been said with truth that their speed changing devices are little less than "mechanical assault and battery."

On the other hand, a modern interurban car equipped with a series parallel controller, either of the drum or contactor type, with a properly divided rheostat, can be accelerated from zero to full speed and brought to a stop with the brake in a manner such that both acceleration and deceleration are at their maximum values and nearly uniform. No better performance than this is needed so far as actual results are concerned, but the inefficiency caused by the enforced use of resistance, and the

fact that half speed and full speed are the only two efficient running points, are the objections.

What is needed is a controller which will permit of the various changes in speed smoothly and without jerks, and at the same time make any desired speed an efficient running point. Of course it is realized that exactly this thing has been and is done under conditions where the extra apparatus required could not be placed in the limited space available on the ordinary motor car. A very close approach to it is now made, however, in the new single phase variable potential controller.

Many will remember the various attempts to control a single motor equipment by means of a rheostat, and through what changes the design of the rheostat had to pass before one was devised which was able to do the work. One of the early forms consisted of a wooden box filled with coils of galvanized iron wire connected to a circle of brass contacts on top. A lever carrying the contact brushes or fingers was operated by a chain or cable from a staff at the dash of the car, with a crank at the upper end. This rheostat usually burned up after a few days due to overheating or to difficulty in extinguishing the arc at the main break. A rheostat was then designed and built by the Thomson-Houston Co. consisting of a group of sheet iron punchings packed in a semicircular iron case and insulated with mica. A radial contact arm carrying fingers passed over projecting iron contacts, and a magnetic blow-out took care of the final arc. This rheostat was very successful and it is doubtful if a better one of similar capacity has ever been devised, as it was almost impossible to destroy it.

When two motors constituted an equipment straight control by resistance was abandoned, and the well known series-parallel Type K controller came into use. This type was carried through increasing sizes until, for heavy motor cars, Type L3 probably represents its maximum size, its weight being about 800 pounds. Even this hand operated drum controller when called upon to break 800 or 1,000 amperes at 650 volts, especially when the speed was so low that little counter e. m. f. was present, failed to satisfactorily perform its duties, and cases are on record where recourse had to be had to the main circuit breaker to save the controller. This and its great weight, which was prohibitive on the platforms of the heaviest

cars, made it necessary to design a controller which could be placed elsewhere on the car where there was more room. At the same time the question of multiple unit control became a necessity and resulted first in the introduction of the system of Mr. F. J. Sprague.

In this system some improvements were made in the details of the series-parallel drum controller, and it was removed from the platform and placed overhead in the hood or inside the car under the seats. Its drum was driven by a pilot motor controlled in a step by step manner by small master controllers on each car equipped, which only carried sufficient current to operate the pilot motors. No particular effort was made at that time to make a drum controller capable of breaking any greater current than had been successfully handled by those of similar size on the platform, nor was it considered necessary at that time. But a little later the increased weight and power of multiple unit controlled trains as well as that of single motor cars necessitated the use of a controller of greater capacity than any form of drum controller than had yet been devised. This brought out the Westinghouse unit switch system of electro-pneumatic control, and the Sprague-General Electric multiple unit controller. A short description of these will be given below.

It was thought best to give the foregoing brief résumé of the controller situation in order to explain the changes which have occurred and to bring the subject up to date. In the meantime many thousands of the old Type K are in use on cars of medium weight and power up to four motors with a total of 200 horse power, and they are giving very satisfactory service. Their success is largely due to the efficient form of magnetic blow-out employed.

The rheostat can almost be considered a part of the series parallel controller, for upon the resistance, capacity and proper division of the former the successful operation of the latter depends. Too little attention to the rheostat seems to be a chronic failing on many roads. Almost as a rule when a road of average size installs the electrical equipment on some new cars the different sections of the resistance are placed in position and the cable taps connected generally with the aid of a diagram from the manufacturer, but often without the intel-

ligent understanding which is necessary to correct mistakes when they occur. It is not difficult to calculate, with a given voltage, what the starting current of a certain equipment should be, and then estimate the necessary resistance, adding the ohmic resistance of the motors and possibly 5 per cent. more for counter e. m. f. and inductance. But after that it is far better to try the first car of a lot with an ammeter in circuit, and discover by experiment whether the car starts easily and without a jerk on the first point, whether the proper amounts of current are used and the acceleration is satisfactory on the other steps of the controller. On one road a very heavy four-motor car required 24 "resistance boxes" and not all were of the same capacity and resistance, and some were in parallel with others. The "try out method" after some changes resulted in a very uniform acceleration. The first point to be determined is the proper amount of resistance for the first step. On some roads where there is a considerable drop in voltage on long lines it is necessary to consider carefully what the average voltage is and arrange the amount of resistance to allow the car to start easily at this voltage, taking care, however, that this resistance is not so low as to cause a bad jerk on starting where the voltage is at a maximum. In extreme cases it is often found that when this rule is followed the car will not start on the first point where the minimum voltage is encountered. The only remedy for this is to re-enforce the feeder system and reduce the drop. But after the first step has been adjusted there is no excuse for allowing "jumping" of the car and abnormal currents on the other steps, since it is but a few minutes' work to correct the error. Where a car starts hundreds of times a day the unnecessary current consumed on account of a badly proportioned rheostat in a year represents a waste which would astonish many a manager.

A point about the ordinary K type of series parallel controller which is usually known to the operating men but often not sufficiently explained, is the fact that the car may be stopped when the trolley is off, or the fuse blown, and the brake inoperative. On a K10 controller and most others this may be accomplished by throwing the reversing switch to the backing position and turning the controller handle to multiple. This

places the two motors in series, but in such a manner that the voltages of the two armatures oppose each other. If these voltages were exactly the same there would be no current generated and consequently no braking. But no two motors are identical and the slight difference in initial voltage gives one motor an advantage over the other and determines the direction of flow of the generated current, and one motor is obliged to reverse its polarity. If the car is moving at sufficient speed the current generated by the two motors will almost instantly rise to an amount sufficient to slip the wheel. As the momentum of the car tends to throw more than the normal weight on the front wheels and relieve the rear wheels, the latter wheels usually slip first. The instant the wheels slip the motor on the same axle ceases to generate current, but as current from the other motor is flowing through it, it is rotated in the reverse direction as a motor.

On four-motor equipments where two motors are permanently connected in parallel, with say, K6 or K14 controllers, it is only necessary to throw the reverse handle, while the controller handle is in the "off" position, to cause the motors to generate, as the circuits are already made, and it is only required to reverse the relation of armatures and fields. With four-motor equipments the reverse handle should not be returned to the forward position until the car stops, for otherwise the contacts on the reversing cylinder may be burned.

A curious example of misunderstanding this subject was recently furnished on a road near New York. A car was ascending a steep hill when the power gave out and the brake failed. As the car began to back down the hill the motorman threw over the reverse lever when he should have left it in the forward position to get the desired braking effect. Fortunately, though the car ran down the hill, no damage resulted. The instructions failed to explain what to do if the car was moving backward and a brake of some kind was needed.

Owing to the many "blow-outs" in series parallel platform controllers caused by the increasing power of four-motor equipments and the consequent inability of the controller to extinguish the final arc, especially when a short-circuit takes place on the car, a demand has arisen for a platform controller which would positively take care of the arc. This is demanded in

some cases where the railway company does not wish to adopt the contactor system in its entirety, and has resulted in the production by the General Electric Co. of the K-28-D controller. In this controller two electro-magnetic switches, or contactors, are arranged in series and used to break the main circuit. These contactors are placed in the main circuit between the controller and the trolley and are located in an iron box in a convenient position under the car. They effectually prevent an arc from holding between the trolley finger and any grounded portion of the controller after the controller handle has been turned to its off position.

The two contactors, operating with resistance tubes which are placed in series with their solenoids or operating coils, are used in conjunction with two small contacts in the controller casing just below the cylinder or drum. These contacts are used for completing the circuit through the operating coils and are supplied with a magnetic blow-out for extinguishing the arc when they open their circuit.

A pivot arm, operated by a projection on the fiber disc at the bottom of the cylinder, brings the two fingers into contact with a cross-connecting strip, thus completing the circuit through the energizing coils of the main contactors. The projection on the fiber disc is so located that the contactor circuit is completed after the main fingers have made contact with the cylinder segments, and in turning off the current the two contactors operate so as to open the main circuit slightly in advance of the main fingers, thereby relieving the latter from all damage due to burning.

Fig. 138 shows the wiring diagram and development of this controller, and Fig. 139 illustrates the additional fingers used in the base of the controller for operating the main contactors.

In the case of heavy motor cars, of electric locomotives, or where multiple unit control is required, one of the two multiple contactor systems of control is now generally employed. Generally speaking, each of the fingers or contacts in the drum controller is replaced by separate switches arranged in groups under the car. In the Sprague-General Electric system these switches or contactors have individual magnetic blow-outs and are operated by electro-magnetic solenoids energized by an auxiliary current taken from the main supply. This auxiliary

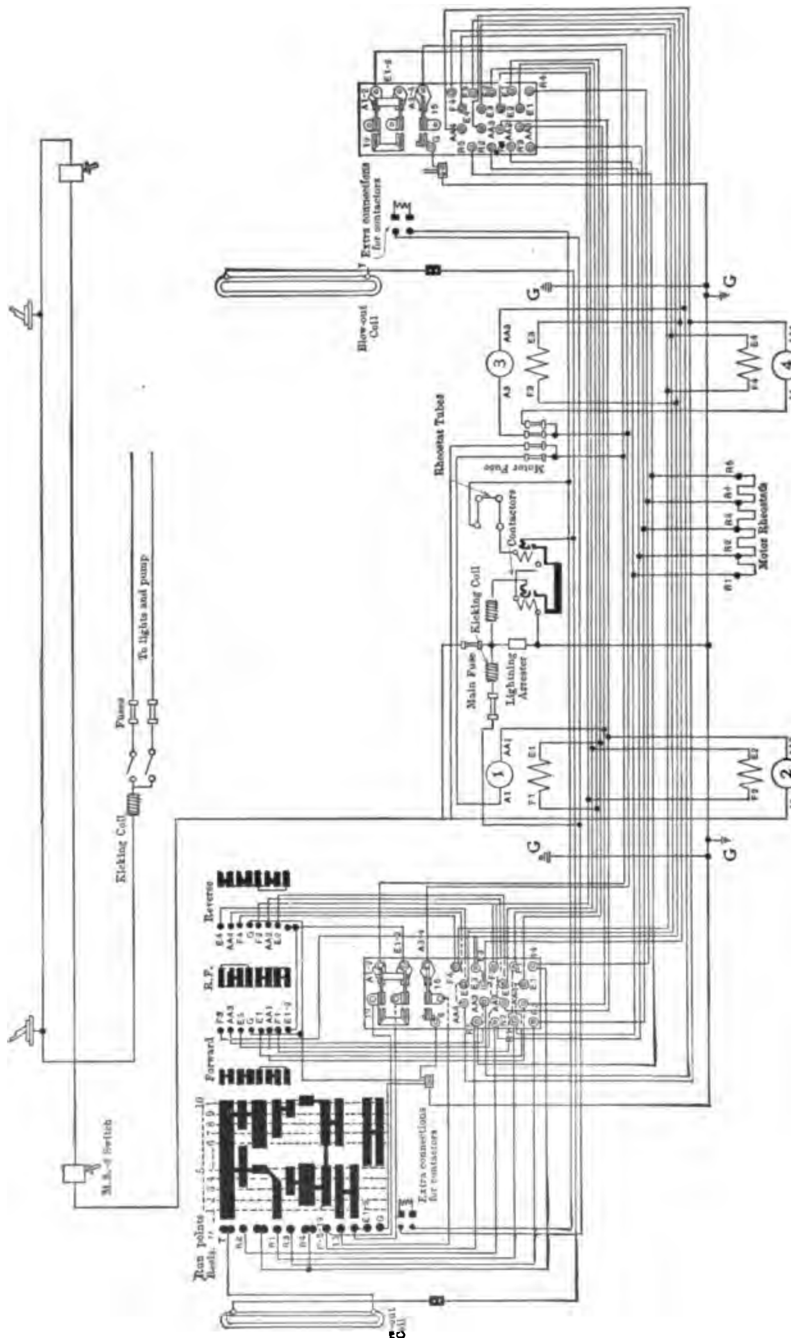


FIG. 188.—Wiring Diagram of K-28-D Controller System.

current is applied and regulated by the master controller operated by the motorman. It may vary in potential due to the line voltages from 300 to 750 volts, and its volume depends on the number of motor cars in the train, being not over 2.5 amperes at 600 volts for a 10-car train. The control cables carrying this current connect all the master controllers in the train so that the latter may be operated from any controller. The operation of the main contactors controlling the power delivered to the motors on any car is thus independent of those on any other car. The main reversing switch is also operated electro-magnetically on each car.

A more recent improvement is the addition of a current-limiting relay. It consists of a solenoid placed on each motor car

FIG. 139.—Fingers at Base of Controller for Operating Contactors.

through which the current of one motor passes. The armature of this solenoid carries a contact disc which opens and closes the energizing circuit for the main contactors. In operation the motorman may turn his master controller handle at once to the full speed position. The energizing current is first admitted to the contactors, which place the motors in series with all resistance in circuit. The current passing through the limit relay draws up its armature until the counter e. m. f., due to the increasing speed of the motor, reduces the current in the motor circuit until it no longer holds up the armature of the relay. The armature then drops and makes connection to the

operating circuit of the next resistance point. The contactors are thus interrupted in their progression at each successive step, so that a nearly constant amount of current is allowed the motors during acceleration until they are in full multiple without resistance. The result is simply predetermined automatic acceleration, over which the motorman has no control as far as an increase is concerned. He may stop his master controller handle at any point, and the automatic action also stops there. There is no doubt of the great advantage of this method of automatic control in the operation of trains. It prevents

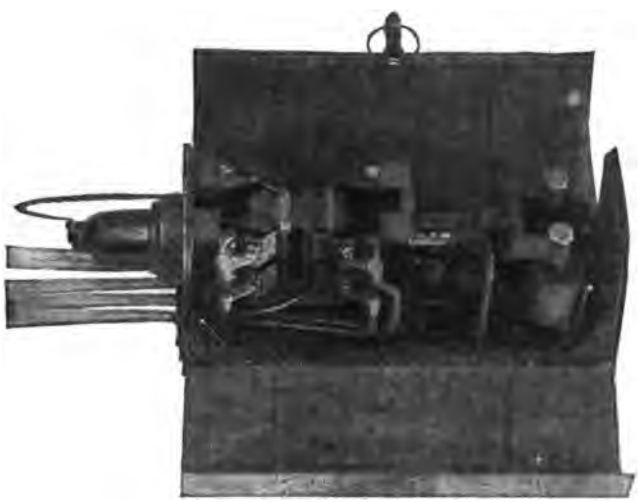


FIG. 140.—Westinghouse Reverser Switch Type 176-E.

the use of excessive starting currents which injure the equipment and increase the cost of maintenance.

Under certain conditions it has the same advantages when employed on single interurban cars, but opinions differ as to the advisability of limiting the acceleration of a city or suburban car, as has been tried by means of certain attachments to the ordinary platform controller, owing to the alleged necessity of sometimes increasing the acceleration to the extreme limit in order to get out of danger. Aside from that, however, the advantages are obvious.

The Westinghouse Electro-Pneumatic system of control practically accomplishes the same results as the foregoing system

and differs from it chiefly in the manner of operating the main contactor switches. These latter are provided with magnetic blow-outs and are very similar to the others, but are operated by compressed air taken from the brake system. The valves which admit the air to the cylinders operating the contactors

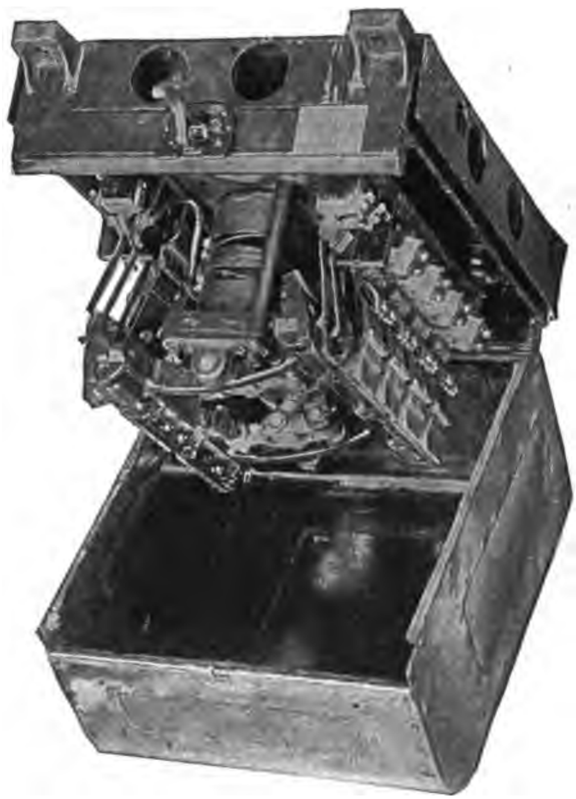


Fig. 141.—Sprague G. E. Reverser D. B. 26.

are controlled electro-magnetically and connected in circuit with the master controllers. The energizing current is obtained from duplicate storage batteries of 14 volts potential on each motor car instead of from the line current. There are certain inherent advantages in the use of an operating current entirely distinct from the main supply. The operation of the contactors is made independent of the line voltage, and of in-

terruptions of current on the forward car of the train. There is also the possibility of stopping the train in the rather unusual event of the simultaneous failure of the brakes and power supply by reversing with the master controller handle in the multiple position, so that the motors act as generators.

Both systems employ reversing switches in the main circuit operated electro-magnetically by the auxiliary control current and also current-limiting relays described above. The master

Fig. 142.—Sprague G. E. Contactor D. B. 41 A. 1.

controllers of both systems have a device by which, if the motorman removes his hand from the controller handle when power is on, the main circuit is automatically opened and the air brakes applied. This is a safety device of great importance if anything happens to the motorman, and obviates the necessity of employing two men in the cab as a precaution against this emergency. Figs. 140 to 145 illustrate the most important features of these two systems of control.

FIG. 143.—(Left-Hand Cut) Sprague G. E. Master Controller.
(Right-Hand Cut) Westinghouse No. 12 Master Controller.

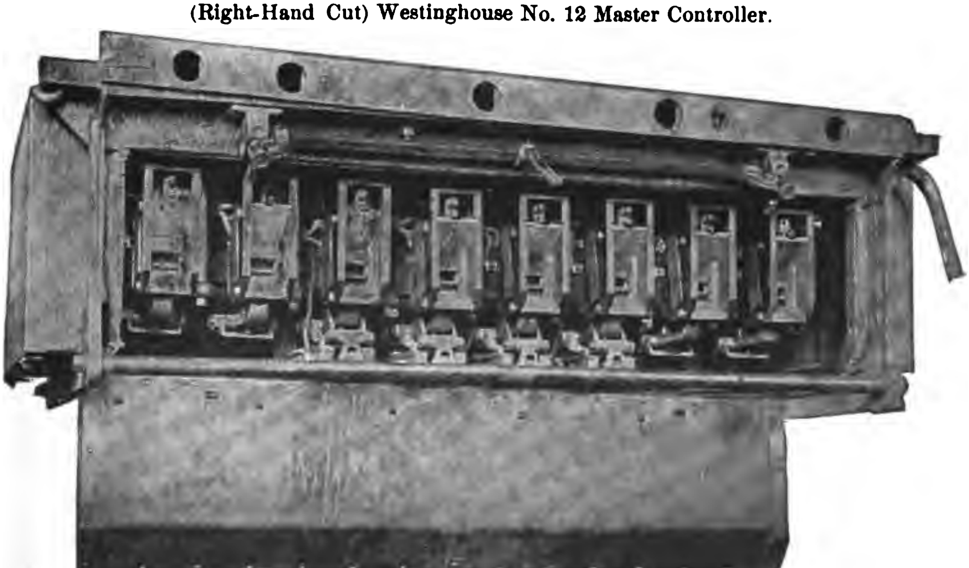


FIG. 144.—Group of Sprague G. E. Contactors, Cover Open.

FIG. 145.—Westinghouse Unit Switch Group, Cover Open.

CHAPTER IX

THE DESIGN OF A MODERN CAR HOUSE

IN suggesting a plan for a car house it is necessary to assume that the land needed is available in the form desired. The majority of car houses have to be fitted to the plot of ground owned by the company, and on that account inconveniences may be incurred which are impossible to overcome. After the size of the house, which is determined by the number of cars to be housed, has been decided on, the most important problem is how to get the cars in or out in the most convenient and practical manner. The most common method is that in which the building is placed at right angles to the main track, and the house tracks join the main track in a succession of curves, sometimes both right and left, thus filling the main line with frogs and switches over which all the through cars have to pass on each trip. A narrow street often compels this form, but where there is room, a second track parallel to the main line should serve as a ladder for the house tracks. Again, if there is a passing point at the house, this ladder track should not be used as a turnout, but the latter should be put in at one end or the other. If there is not room for two tracks in front of the house the proper method is to put in a gauntlet in the main line, using it for the ladder. This eliminates a large proportion of the troubles arising from continually running the equipment over the switches.

In the design suggested here the building is placed parallel to the main track with offices, waiting rooms, etc., on the side nearest the track. Entrance and egress for the cars should be provided at both ends of the house by means of two ladder tracks leaving the main line and turning approximately at right angles to the latter, one at each end. This method places only two switches in the main line, without regard to the size of the house or the number of cars in use. (See Fig. 146.) The method is entirely practical and cheaper if used only at one

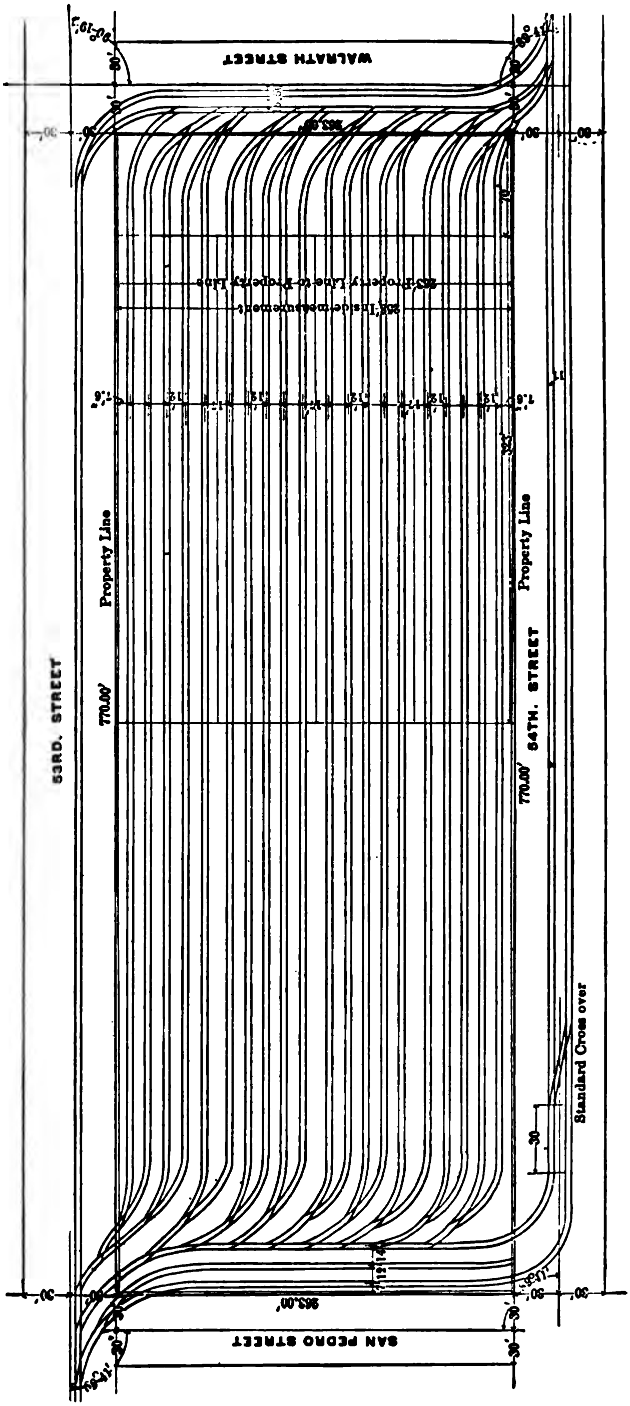


Fig. 146.—Plan for Car House Tracks.

end, thus necessitating but one switch in the main line. A difference of opinion will be found as to the advantages gained by entering and leaving the house at both ends, and whether they are worth the expense of the additional special work. These advantages are obvious though, for they not only facilitate quick movements of cars during regular operation, but in case of fire it becomes possible to run the cars out in perhaps half the time, and possibly saving the cost of the added facilities many times over. The point that should decide the question is the size of the house and number of cars, for it is, of course, not advisable in a small house.

Three general styles of buildings are in use; that most commonly seen is a large brick building with a peaked roof supported by steel trusses. Later designs are not so high and have the mill or "saw tooth" type of roof. (Fig. 147.) This provides an abundance of light and reduces the fire hazard.

The latest design, however, is constructed entirely of steel and reinforced concrete with a low roof, almost flat, of the same material supported by concrete columns. (Fig. 148.)

The trolley wire in the building is replaced by either Tee or channel irons attached to the bottom chord of the roof trusses and properly insulated from them. Mistakes have been made by constructing the roof too low, so that the trolley pole could not be raised to relieve the tension on the springs. This is important on a road where there are high trolley wire crossings (22 feet) over steam roads, as the springs, if not relieved, may not have sufficient tension at that height and the wheel may leave the conductor. Ample light must be provided by large side windows and skylights. As mentioned above, on the side of the house toward the track and occupying a width of 20 to 30 feet, should be located the offices of the superintendent or despatcher, the foreman and the accounting clerks. Next should be the waiting room for passengers if it is necessary, and then the lounging or recreation room and locker room for the men who run the cars. This latter room should be well fitted up and, if necessary, limited accommodations for sleeping provided. There should be a storeroom next, and all these rooms may not occupy half the length of the house. Following this should be the machine shop and blacksmith's forge for all light repair work. It is not necessary to provide a partition

between the shop and the main house, for the side windows here will assist in lighting the house.

One of the most important points in the general plan of a car house is the design of the floor and the pits. In no case should a warm car be stored over an earth floor, for the heat of the motors will draw the moisture from the earth, and it will induce sweating within the motor frames which may cause trouble. Many car houses have suffered for lack of pits, and

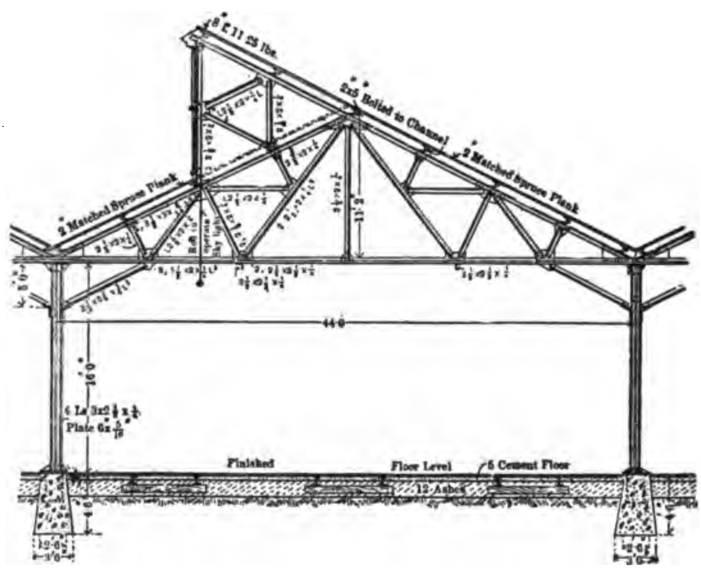


FIG. 147.—Mill Roof Type of Construction.

some managers have expressed the opinion there cannot be too much track space devoted to pits, for a track in a house without a pit is of no use except for storage, and if cars are on such tracks they must be run to another track containing a pit in order to be inspected. This has caused many modern car houses to be equipped with pits under all tracks, and the method adopted has been to use a subfloor of concrete, properly drained, on which the tracks are carried on posts or piers of brick, concrete or cast iron, spanned by stringers or I-beams, which support the rails. It gives a comparatively clear space under all cars, which can be lighted by incandescent lamps placed along the stringers, and pit jacks carried by four-wheeled

trucks can be used on the subfloor. The space between the tracks is floored sometimes with plank, but a concrete arch is much better, and directly beneath is carried the steam heating pipes. Possibly, in large houses, it may not be advisable to have the entire floor space of this construction, but not less than half should be.

In advocating so much pit space it will be understood that the principal object is to facilitate inspection, and not for the purpose of doing much repair work from below. Pits enable repair work to be done both above and below, and while it is

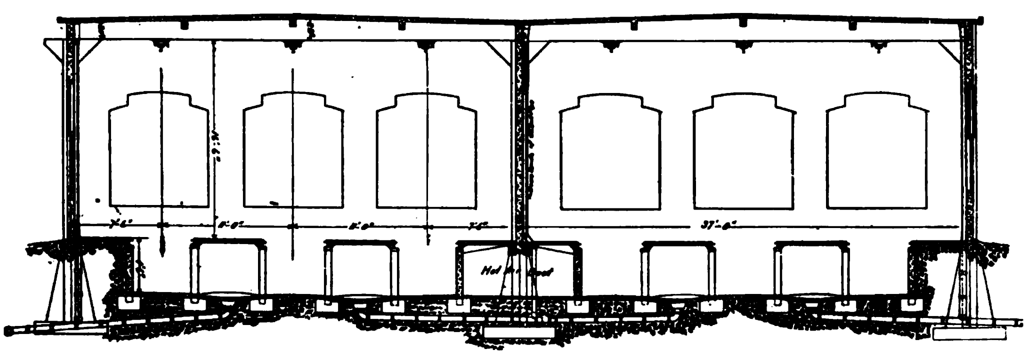


FIG. 148.—Section through Concrete Steel Car House.

considered best to do all possible from above, there is frequently something which can be more easily done and seen from below. To work from above, on trucks or motors, it is of course necessary to raise the car to get out the trucks. There should be at least one pit equipped with the motor-driven jacks used in the main repair shop, and on a post convenient to this pit should be a jib crane with an air hoist, capable of lifting armatures, motors and wheels and axles. Opinions differ as to whether new wheels should be put under a car in an operating car house; some preferring to send the car to the shop. If the facilities mentioned above for this work are provided, they are the same as are used at the shop, and are not expensive when we consider the dead mileage the car must make to and from the shop, keeping the car out of service probably a whole day; whereas the work could be done in the house in two or three hours.

Compressed air is very useful about a car house in many ways, and the equipment should always include a motor-driven air compressor, with a reservoir of large capacity, say from 50 to 100 cubic feet, and an automatic governor to keep the pressure at 80 to 100 pounds. The air should be piped to several convenient places, preferably in the pits, where a hose and nozzle can be attached and air used for cleaning seat cushions, controllers, motors, etc. A portable air drill is often useful when a hole through a truck frame or some part of the brake rigging is needed. On roads where the cars are equipped with air brakes supplied by independent motor-compressors, the latter are sometimes used to supply air for the purposes mentioned, but it is better to have the outfit fitted with a larger compressor than is used by the cars, for the car compressor is frequently overheated and damaged when used for this purpose.

As steam heat is a necessity in a car house, especially in the more northern latitudes, a boiler room should be suitably located, possibly in a separate building outside the house. In some cases the steam pipes are laid close to the floor, under the cars, where there are no pits, so the cars are easily dried and snow or ice melted.

The list of machine tools ordinarily considered necessary in a car house of average size is given below:

1 grindstone.
1 emery grinder.
1 20-inch drill-press.
1 engine lathe, 16 inches x 6 feet.
1 forge.
1 anvil.

Fire Protection and Insurance

So-called fireproof construction of modern car houses has undergone a number of radical changes in the past few years. Seemingly it was not realized until recently that the main object to be sought must be the protection of the stored cars, not the building. Almost any one-story building, not a wooden shed, constructed of brick or concrete and steel is reasonably fireproof, but the danger lies in the taking fire of the long closely packed rows of stored cars to be found every night in

the houses. Being of an exceedingly inflammable nature, even with the trolley pole pulled down, a fire caused by defective wiring may have smoldered during the day and become the incipient cause of a conflagration. This is the situation which is responsible for the great hazard existing in all car houses. There is little danger of the building taking fire first and communicating to the cars, provided reasonable care is exercised in the disposal of rubbish, oily waste, etc.

Many car houses have been built of brick with a slate roof supported by steel trusses of wide span covering a large area. Sometimes as many as 100 cars are stored in such buildings, which were considered fireproof. They would be fireproof if the stored cars were built of steel instead of wood, but experience has proven that the intense heat from a lot of burning cars in such a building soon warps the steel trusses supporting the roof all out of shape, resulting in the immediate fall of the roof, thus completing the destruction.

This has led to certain fundamental requirements to reduce the risk. First: Too many cars must not be stored in one inclosed space. Second: The roof must not fall in. Third: Facilities for getting water into the burning cars at once, either automatically or otherwise, must be provided. Fourth: A plan for rapidly removing undamaged cars from the building is necessary.

In regard to the first requirement it has been deemed essential that the house be divided into bays separated by fire-walls covered by low roofs above which these walls project; that these bays contain no more than 3 tracks and inclose not more than 10,000 square feet of space.

By some it is contended that the roof should be supported by short trusses spanning the bays and constructed of wood which has been subjected to a fireproofing process, the roof itself being of metal. Metallic curtains are also suggested as being advisable, arranged to be lowered into position and raised when necessary, placed at suitable intervals across the bays. Others prefer a low reinforced concrete roof properly designed so that fire cannot readily cause it to fall. These methods fulfill the second requirement.

The third necessitates efficient protection by a reliable water supply, sprinklers, hydrants, hose, watchmen and a good local

fire department. In all consideration of car-house protection the fact should be remembered that a car is not only a very inflammable structure, but also one into which it is very difficult to get water quickly under ordinary conditions. All car-house fires are very rapid; in most cases not more than 35 to 40 minutes are sufficient to accomplish the work of destruction. Fire-fighting apparatus should be so arranged that it is quickly available, and a few extra hydrants equipped with reels of hose and extinguishers of various kinds will often prevent a serious conflagration. The racks of open pails filled with water often seen, would do better service at the outset if filled with sand.

The fourth requirement—that the cars be quickly removed—is a difficult problem in most cases. Some houses are built with a slight descending grade from the rear to the front of the house, the idea being that employees may run from car to car and release the hand brakes, thus permitting the cars to run out of the house by gravity, whence they are moved to a place of safety. In the case of an entrance at each end the grade could run both ways from the center of the building. In some fires many cars have been saved by employees placing the trolley wheel on the wire and the controller on the first point, thus allowing the cars to run themselves out under power, but it is evident that this takes more time than the other.

A basement is nearly always an undesirable feature in a car house, as it usually becomes a receptacle for various kinds of rubbish, and is sometimes used for the storage of even more inflammable material, as oils and paint. A second story should also be avoided where possible, even when used for offices or employees. If there is plenty of space there should be no difficulty in providing the necessary rooms on the ground floor. That these latter restrictions reduce the fire hazard is generally admitted, though in many cases lack of space prevents their employment.

Recent tests have shown that a properly installed sprinkler system is one of the best methods of fire protection in car houses. From the fact that such systems have been long employed in factories, mills and all kinds of buildings containing inflammable material it is a source of some surprise that they have not been placed in car houses until very recently. In most

cases the reduced insurance rate obtainable on account of their introduction will pay for them in a few years.

A typical installation of one of these sprinkler systems is shown in Figs. 149, 150, and 151, which is in one of the car

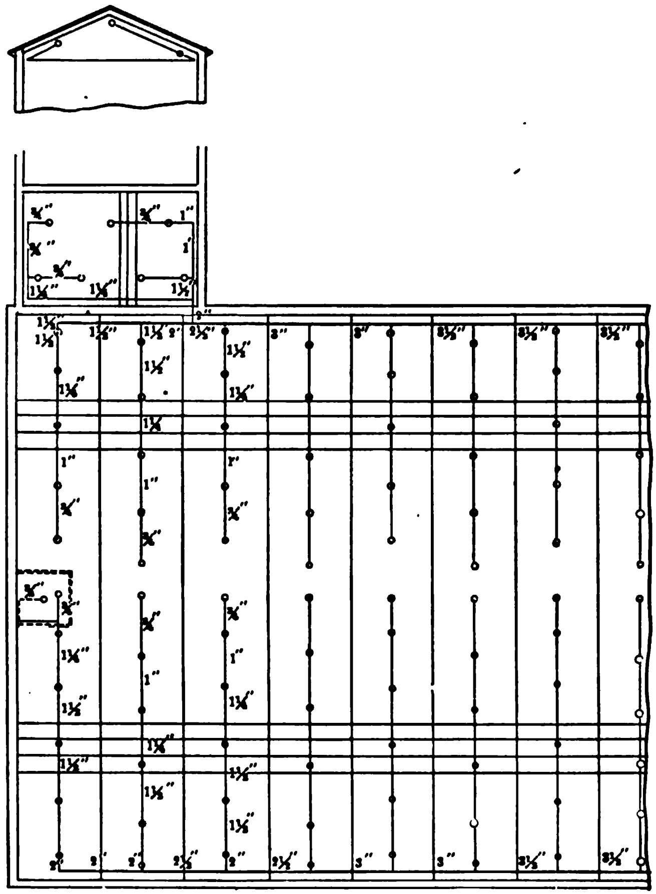


Fig. 149.—Plan Showing Arrangement of Ceiling Sprinklers, North Albany Car House, United Traction Company.

houses of the United Traction Co. of Albany, N. Y. The plant includes two main operating and storage houses separated by a narrow alley. They are built of brick throughout, with concrete floors and pits, and a plank roof supported on steel

trusses, with a covering of slag roofing on top of the plank roof. In such a construction ceiling sprinklers as well as aisle or side line sprinklers are considered necessary on account of the height of the roof, as shown in the cuts. Ceiling sprinklers are so spaced that each one covers approximately 70 square feet. The aisle sprinklers are not over 7 feet apart and 8 feet above the car-house floor. Where cars are more than 4 feet apart two lines are placed in each aisle. The entire plant,

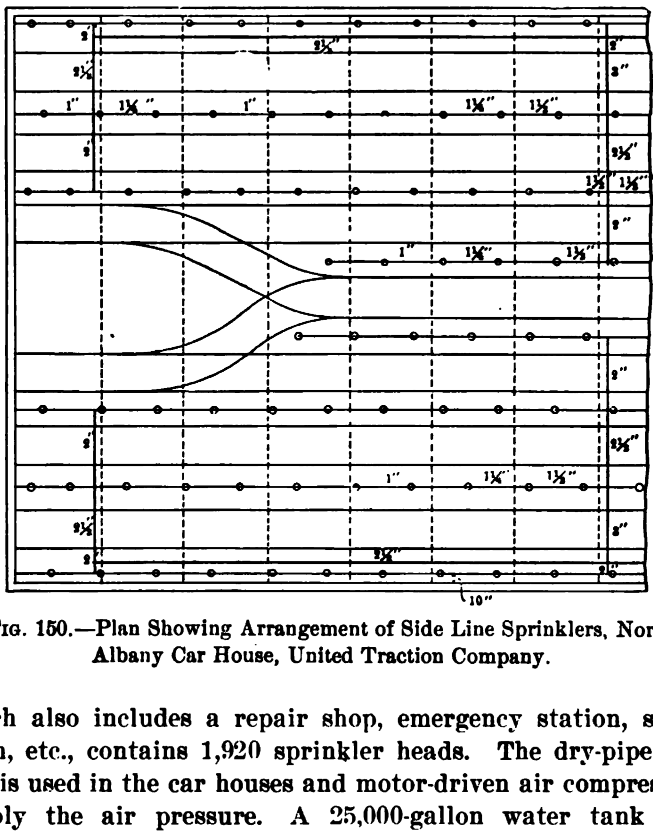


FIG. 150.—Plan Showing Arrangement of Side Line Sprinklers, North Albany Car House, United Traction Company.

which also includes a repair shop, emergency station, storeroom, etc., contains 1,920 sprinkler heads. The dry-pipe system is used in the car houses and motor-driven air compressors supply the air pressure. A 25,000-gallon water tank was placed on a steel structure 75 feet high, as an auxiliary to the city water pressure.

Some of the largest street railway companies carry their own insurance covering all their properties. In carrying out this plan a certain fund is set aside and invested, and to this

is added yearly or monthly an amount about equal to the premiums they would probably be required to pay the insurance companies for the same insurance.

An important factor in this scheme of self-insurance is a thorough, regular and systematic inspection of all the property covered, with the end in view of preventing fires. One company employs two inspectors whose entire time is given to visiting the car houses, power stations and buildings in regular rotation, and whose duty it is to report in detail the condition

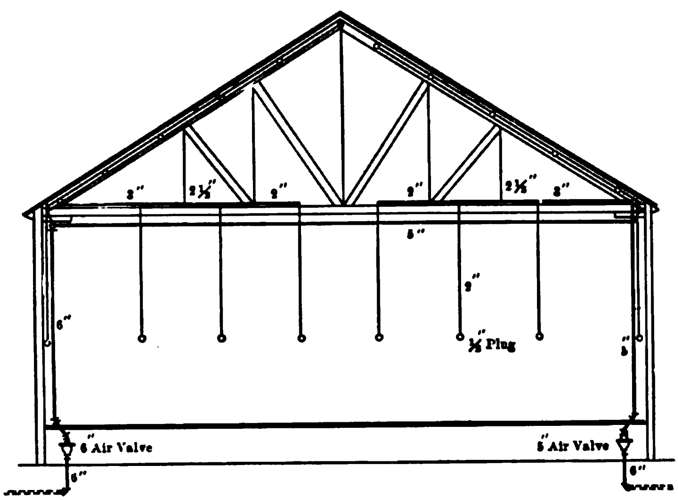


Fig. 151.—Section through North Albany Car House Showing Combination of Ceiling and Side Line Sprinklers.

in which all premises are found. They are also instructed to call attention to any conditions that might increase the fire hazard. The inspectors make a daily report to the general manager on a blank which includes some fifty questions, each of which requires an answer concerning some detail in relation to the fire risk.

In addition to these rigid inspections, once in six months an outside expert examiner makes an independent inspection of all the property. At all of the principal buildings the precautions against fire include the placing of hose and other apparatus at advantageous points, and the designating of these points by

notices printed on the walls near each piece of apparatus which call attention to the necessity for keeping these locations free from dirt and rubbish that would interfere with the prompt handling of the fire-fighting equipment.

Car House Lighting and Heating

Further attention should be given this important subject, for it is a problem which admits of no easy solution. In some cases it is not solved at all, and frequently very badly done.

A house used for purely storage purposes, which is not an operating car house though it may be an adjunct to one, seldom requires any heat. Rows of incandescent lamps over the aisles in fixtures attached to roof beams, if the latter are low, should give sufficient light if spaced two car lengths apart. If any small repair work should be done the light from the car may be used if needed. But light enough to see and move cars should be sufficient.

In the case of an operating car house conditions are entirely different. Here are pits for inspection and light repairs which must be lighted and heated, as well as the building itself. The source of the heat for the entire space devoted to cars should be in the pits. This allows the hot air to rise through the equipments and melt the snow and ice with which they are frequently incased. Little heat is needed elsewhere than in the pits except in the repair shop and offices.

As to the methods of obtaining heat it seems impossible to secure satisfactory heat without a steam boiler. While some car houses are heated by stoves these fail to place the heat in the pits, and in consequence are of little use. A car house adjacent to a steam-driven power station solves the steam question, but where such is not the case a boiler must be installed in the most convenient place and the house heated either by the direct or indirect system. In the latter the air is blown over steam coils and then conducted through flues to the pits. These flues may extend throughout the length of the house under the floor between pits, with occasional openings pointed diagonally downward toward the floor of the pits on each side. This plan is, of course, only available where the space beneath the tracks between pits is open, which is the usual present style of construction. Where

pits are short, but little more than a car length, and closed, the flue openings may be in each end near the bottom and the hot air blown horizontally.

In the direct steam system where open pits are in use the radiation pipes can be run beneath the house floor between pits where they are out of the way, and the heated air from the pipes must pass into the pits before it can rise. In closed pits the problem is more difficult, and while the steam pipes are sometimes placed along the sides of the pits, they are in the way of repair men. They have been placed in recesses at the sides, which is a considerable improvement.

In the lighting of operating car houses arc lamps have no place unless the repair shop is of sufficient size to require one or two for general illumination. But in the main body of the house or offices they are unnecessary, and in view of the fluctuating nature of the current usually employed they should be entirely eliminated.

Incandescent lamps between the lines of cars about one car length apart, attached to pipes which extend down from roof supports, or from a plank laid from truss to truss parallel with and above the aisles, will give abundant light. The lamps may be furnished with a white metallic shade for reflecting the light downward. They should be from 8 to 10 feet above the floor.

Pit lighting is the most important and should be laid out with considerable care. The lamps should be placed along the sides of the pit about 10 feet apart at the pit side of the beam supporting the rails. In open pits this is usually an I-beam, and protection is afforded by the projecting flanges. The wiring should always be in iron pipe conduit. In closed pits where the supporting beam is frequently of wood a recess should be provided for the protection of the lamp. Fig. 152 illustrates this.

In regard to the source of current supply much depends on the distance from the power station and on the general condition of the feeder system. It goes without saying that a separate source of supply than the power circuit is desirable for many reasons. Experience with both city and interurban systems has shown that this is seldom practicable on account of the expense. If an independent ungrounded circuit of 120 volts, either d. c. or a. c., were available, it would solve the

question at once. But in most cases a separate 550-volt feeder, if the power station is not too distant, is the best that can be done economically. Many such houses, however, are compelled to get their lighting from the regular power feeders in the

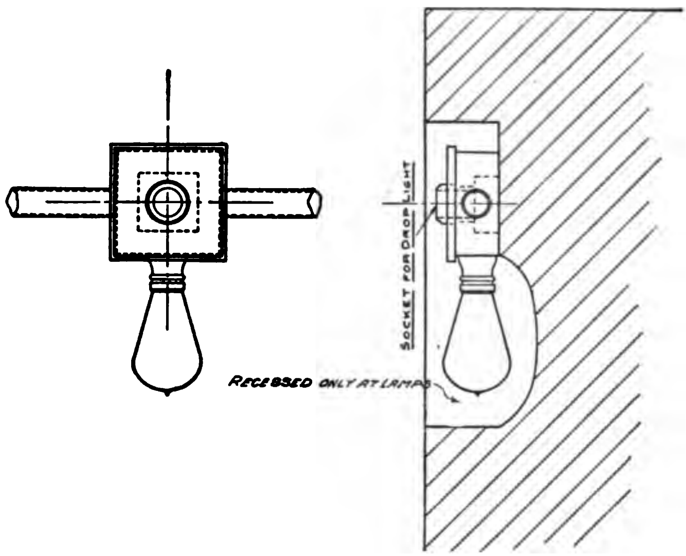


FIG. 152.—Method of Pit Lighting.

vicinity, subject to more or less fluctuation and liable to go out, if that particular feeder gets in trouble. It would seem, however, that where high-tension a. c. transmission is used a small substation equipped with static transformers only would furnish a satisfactory lighting current.

CHAPTER X

THE GENERAL DESIGN OF A MODERN REPAIR SHOP

It is not proposed to attempt to submit here a complete design of a model shop, but to illustrate some of the special features in modern shops recently built, and in a general way suggest a layout of a shop which seems best adapted to the class of work. In most manufacturing establishments the designer endeavors to arrange the plan so that the raw material is brought in at one end and the finished product sent out at the other. This is not so necessary in a car repair shop, as will appear later. The general layout of the plant should include two long one-story buildings parallel to each other and separated by a space 70 to 80 feet wide. One building should be at least as wide as the length of two long cars so that each track could accommodate two cars indoors, making the total width about 110 feet. In this building should be the stripping and inspection room, the paint shop and erecting shop, and other departments in which work is done on the car body. The opposite building should be preferably of the same width and contains the winding room, the wood-working shop, the machine shop, the blacksmith shop and the truck shop. The general storeroom should be located near the center of one of these buildings, or in a separate building conveniently located, in which case the offices may be included in the same building. Between these two buildings and extending beyond them at each end is the transfer table, about 50 feet wide. Fig. 153 shows a form widely used. It should be electrically driven upon four or six rails located in a shallow pit. The sides of this pit form a line parallel to the buildings at a distance of about 10 feet from the doors. This leaves 10 feet of track outside of each door between it and the table. This space is often useful to place a truck temporarily, and allows room to open the doors. Objection is sometimes made to jacking up and repairing two cars on the same shop track, because of the

probability of the rear one being completed first and having to wait for the other. This objection could be overcome if it was deemed advisable to construct the other side of the building with doors to each track, and shop tracks leading to a track parallel to the building, and running around to the transfer table. It would then be possible to bring trucks to the car in the rear, and haul it out. This method is not unusual in the shops of car builders. Where possible there should be car storage yards at both ends of the transfer table line, so that all cars can be readily taken into or out of the shop. In moving cars in or out of the shop from the transfer table, whether the cars are on their own trucks, or temporary shop trucks, the usual method is to disconnect the transfer table gear and connect its motor to a windlass on the table and by means of blocks and a rope move the car; or sometimes a separate motor for the purpose is placed on the table.

In suggesting a general plan of such a shop it is, of course, necessary to assume that sufficient land upon which to build is available in all directions, but it is true that this is seldom the case, and it frequently becomes necessary to modify the design to fit the land. There is little necessity in a shop of this kind for more than one floor, unless there is insufficient space, and this insures plenty of light, one of the most important considerations, whether the roof is of the steel-truss design with monitor and skylights, or the so-called mill construction. If the offices are in a separate building, which is sometimes advisable, it might be two stories in height. Whatever the style of construction for the shop buildings, and probably the mill style of steel and reinforced concrete is the best, each department should be separated from the next by a fireproof wall, and the whole shop equipped with a sprinkler system as well as the usual hose connections.

Reinforced concrete construction is now being utilized to a considerable extent in the construction of shops and car houses, where it replaces brick and, to a large extent, steel. The concrete mixture usually consists of one part Portland cement, two parts sand, and four parts crushed limestone. Another mixture is one of Portland cement, three of sharp sand, and four of crushed stone. The quality and fineness of the cement will vary the proportions of the mixture. Supporting col

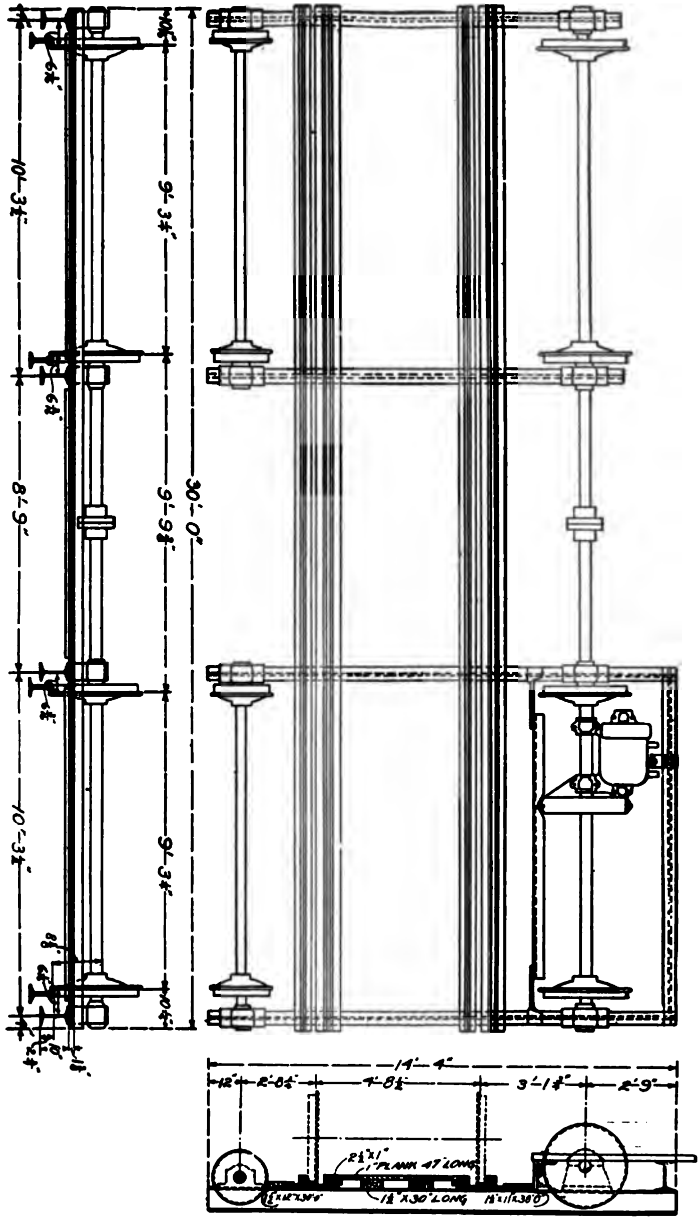


FIG. 153.—Type of Transfer Table Widely Used.

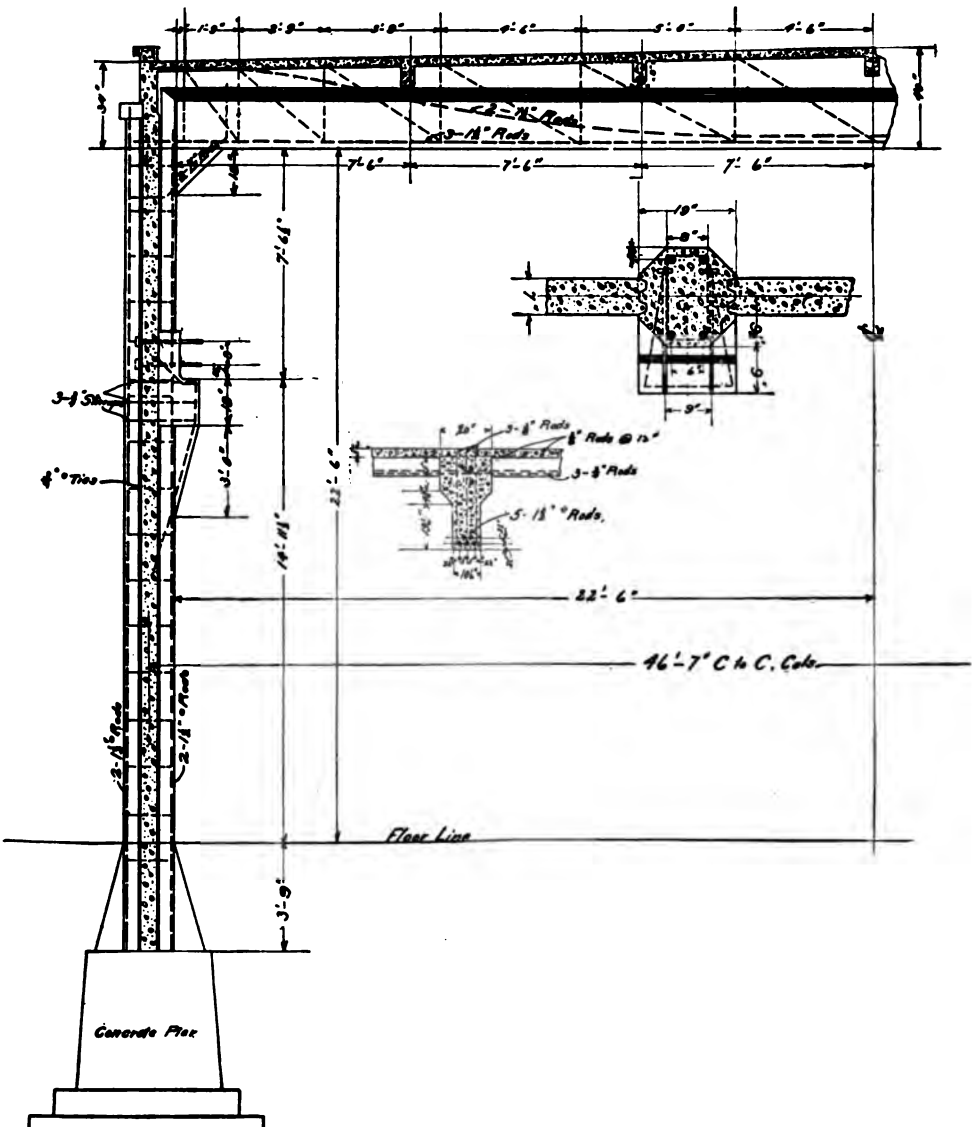


FIG. 154.—Half Section of Shop Showing Reinforcement.

umns, walls, roof girders, and even the roof slabs themselves, are moulded or cast of concrete in wooden moulds, either in position or on the ground, and afterwards placed. Columns are reinforced by iron rods spaced around the circumference of the column and tied together by iron bands, all of which are placed in position within the wooden mould before pouring and tamping the concrete. Smaller columns are sometimes cast around a cylinder of wire netting, a little smaller in diameter than the column, in addition to longitudinal rods. In girders

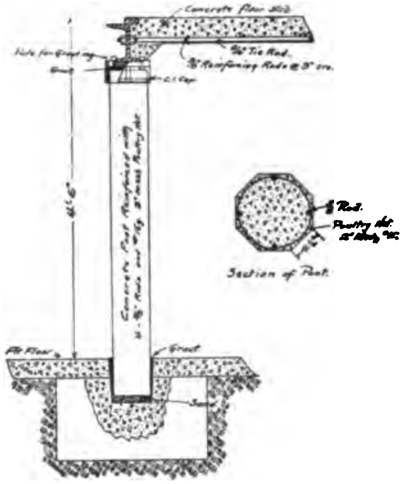


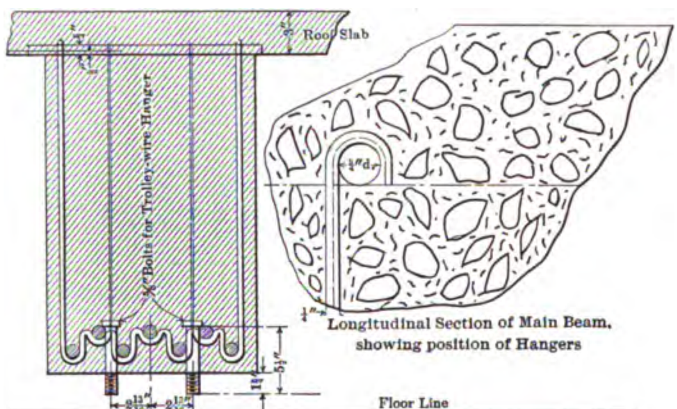
FIG. 155.—Details of Pit Posts.

the rods are arranged as are truss rods, lowest in the center and rising at the ends of the girder. Roof slabs, as thin as 3 inches, are cast in place with wire netting or small rods integral with them. The walls between window casings and columns are boxed with wood, the interior poured full of concrete, and wood then removed. Some details of reinforced concrete construction are shown in Figs. 154, 155, 156. This material is absolutely fireproof and of great strength and durability.

In the design of shops of late, the question of fire protection is never lost sight of, so that now there seems to be little or nothing used in the construction of the buildings which can burn, the only inflammable material being the contents, in the

shape of cars and stores. The designer aims to protect one department from another, to keep fire from spreading, and there are those who believe that the larger departments, as the paint shop, the erecting shop, etc., should be separate buildings. It would seem, however, that when a shop is built of concrete with fire walls between departments all could be under one roof, except possibly oil and paint supplies.

The heating and lighting of a repair shop are of the utmost importance. In this connection it becomes necessary to install



Cross Section of Main Beam,
showing Suspenders for Reinforcing Rods
& position of Bolts for Trolley Bracket

Fig. 156.—Details of Beam Reinforcement.

a number of boilers, either in one of the main buildings, or in a separate boiler house. The conditions of power distribution will determine whether it is advisable to install an engine and dynamo, or frequency changers and transformers to obtain a proper current for lighting. Alternating current inclosed arc lamps suitably distributed, and supplemented by incandescent lamps where necessary, form a good method of illumination. Power for the shop tools, and for driving air compressors, can usually be obtained from special feeders at 500 volts. It is advisable to concentrate the power and lighting distribution points, as well as the heating, in the boiler plant, so that they may be under the control of a competent engineer. The heating and lighting of the paint shop require more attention per-

haps than that of the other departments. Arc lamps are seldom advisable in this case, unless desired for general illumination and hung high. Rows of incandescent lamps, of 32- or 50-candle power each, between the shop tracks, hung on flexible cords at about the height of the tops of the windows, when the car is jacked up, give the best results. Throughout the rest of the shop arc lamps are desirable for general illumination, and incandescent lamps about machines, and especially in a portable form with extension cords, shades, and attachment plugs. These can be used on almost any work done at night, especially in pits under trucks and inside cars, in the erecting shop and paint shop.

Heating should be done either by the direct steam system, with pipe radiators properly distributed, or by the indirect steam system. In the former it is difficult to find suitable locations for the radiators. The method sometimes used of suspending them at a considerable elevation above the floor is not at all desirable, for the heat rises, and not until the room is full of hot air does it approach the floor, where it is most needed. In consequence the floor is always the coldest part of the room. About the only place for radiators in the paint shop and erecting shop is midway between the shop tracks and parallel with them. This may necessitate increasing slightly the track center distance in order to give sufficient room. The indirect steam system is undoubtedly the best when conditions warrant its use. In this system the radiating surface for the steam is concentrated in one place for a whole building. This radiator is usually located overhead near the center of the building, and inclosed. Hot-air flues lead in all directions overhead, throughout the building. At regular intervals, in convenient places, outlets project downwards. A powerful blower then supplies air to the steam coils, which is heated in passing through them, and is forced out through the flues. The warm air is then forced from the outlets toward the floor, from which it slowly rises. This system is especially applicable to the paint shop, as it uniformly warms the air about the painted or varnished cars, and it occupies no useful space.

In suggesting the location of the various departments in a shop plant chiefly consisting of two long buildings separated

by a transfer table, we will designate these buildings as A and B.

Building A, which is 100 feet wide by 400 feet long, contains first the offices, occupying 40 feet of its length; then the car-washing room and the stripping room, each 20 feet long; then a storeroom of paints and painters' supplies. Next the paint shop, containing say 5 shop tracks spaced 16 feet centers or providing for 10 cars at a time. No pits are needed in these tracks. The wood-working shop should come next.

FIG. 157.—Armature Jack.

This room should be about 100 feet long, and requires several shop tracks for the purpose of transporting heavy material, as sills, etc., to and from the transfer table. It also includes the cabinet shop. The boiler room should be next and is usually 12 or 15 feet below the floor level, so that shavings, etc., can be sent down in gravity or suction chutes. This room need not occupy over 30 feet of the length of the building, and part of the width could be at the shop floor level, containing air compressors and any electrical machinery or switchboards needed. It is to be understood that the entire

shop is electrically driven, most of the tools being driven in groups by different motors. Next to the boiler room is the upholstery room, which requires little space, and the winding room, where general electrical repairs are made. Next is a lavatory occupying a suitable space in the end of the building.

Building B. We assume that Building B is the same width as A, or about 100 feet. The first room in this building is the erecting or equipping room. This room should contain about 10 shop tracks on 16-foot centers, extending only to about the center of the building, and each containing a pit 40 to 50 feet long, with steps at each end. The depth of the pit should be 50 inches from top of rail. In the bottom of the pit, which is

FIG. 158 —Power Operated Car Jack.

of cement or concrete, is used a small truck carrying a hand jack for lowering and removing armatures or motor frames. Fig. 157 shows one style. In place of the old method of jacking the car body off the trucks by hand, rolling the latter out, and placing the former on timbers or blocks, there are several methods of attaining the same thing with much less labor and time. Fig. 158 shows a method by which six screw jacks are raised simultaneously by shafts carrying worm gears and connected by bevel gearing to another shaft which is driven by a motor. Each pair of jacks on the same side of the car, are spanned by a steel I-beam, and these two beams support a pair of timbers passed under each end of the car body. The safety of such an arrangement is apparent. Fig. 159 shows it in use.

Each pit in the erecting shop should be equipped with these jacks, and each pair of pits at their outer end, near the doors, should be served by a jib crane attached to a post midway between pits. These cranes should be equipped with compressed-air hoists capable of lifting from two to three tons. As arranged each crane serves two pits. One type of jib crane is shown in Fig. 160. The great utility of a traveling crane both here and in the truck shop is fully recognized, but conditions must warrant the expense. Back of these pits in the other

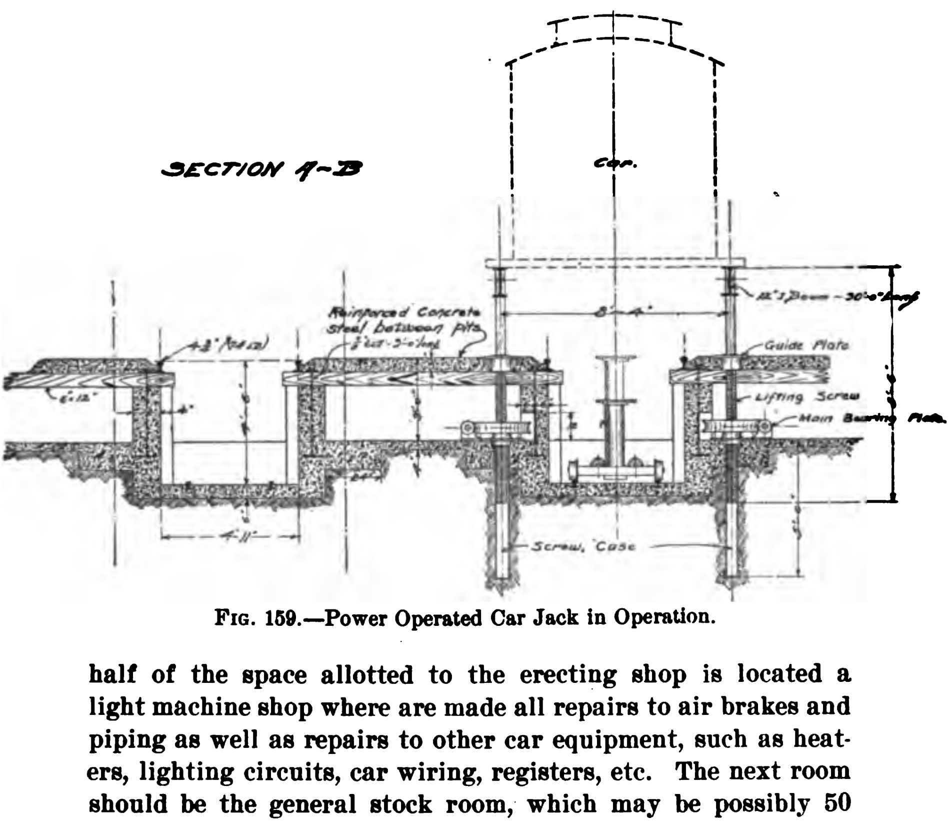
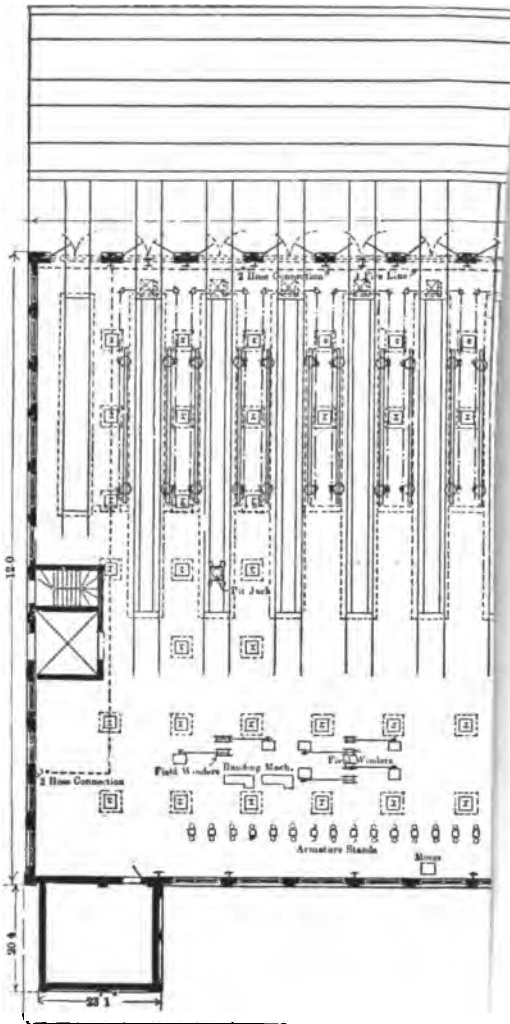


FIG. 159.—Power Operated Car Jack in Operation.

half of the space allotted to the erecting shop is located a light machine shop where are made all repairs to air brakes and piping as well as repairs to other car equipment, such as heaters, lighting circuits, car wiring, registers, etc. The next room should be the general stock room, which may be possibly 50 feet wide. A lavatory and locker room should be included in the next space, about 12 feet wide, but not necessarily extending the full width of the building. The next is the truck shop, which should contain at least five shop tracks on 15-foot centers, extending only to the center of the building, the room



2 Hose Connection
Pit Jack
Field Winders
Banding Mach.
2 Hose Connection
Armature Stands
Motor
120
20 4
23 1

being about 90 feet long. Each track should contain a pit, but the latter need not be over 20 feet in length, so that two trucks may be over the pit at once. If considered advisable a traveling crane should cover these tracks, if not the jib cranes with air hoists should be used. Back of the truck shop in the same room should be the heavy machine shop, which includes the wheel shop. An extra shop track without a pit should connect the wheel shop with the transfer table. Fig. 161 shows

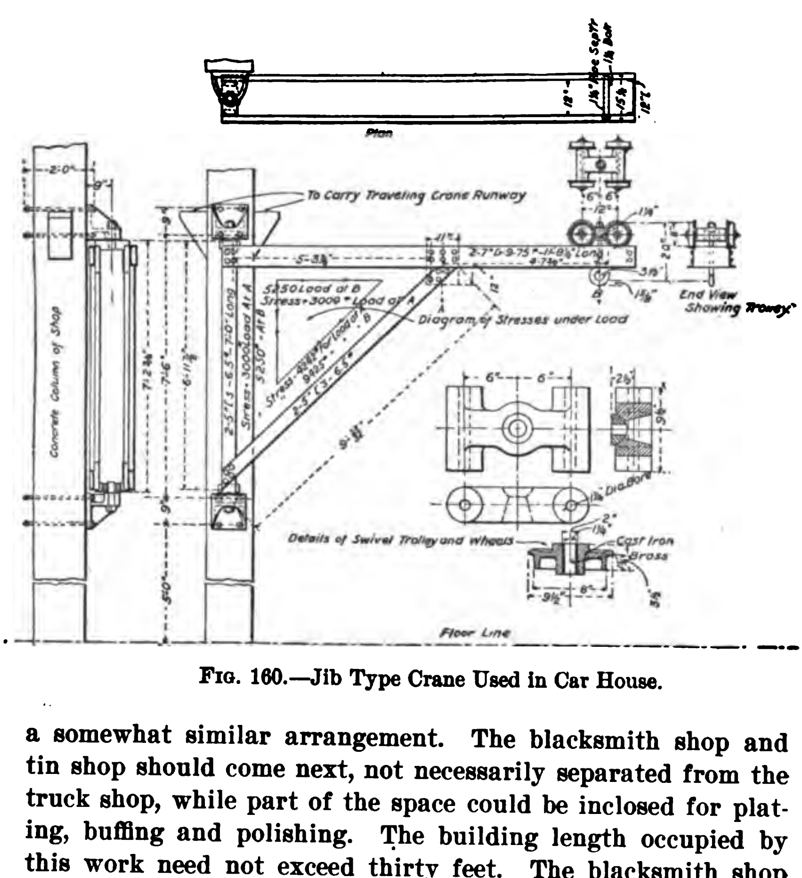


Fig. 160.—Jib Type Crane Used in Car House.

a somewhat similar arrangement. The blacksmith shop and tin shop should come next, not necessarily separated from the truck shop, while part of the space could be inclosed for plating, buffing and polishing. The building length occupied by this work need not exceed thirty feet. The blacksmith shop should include a 2000-pound steam or compressed-air hammer, and a bulldozer. In a part of the space occupied by the blacksmith shop, preferably nearest the transfer table, could be located a wheel-grinding device, the dust from which would be

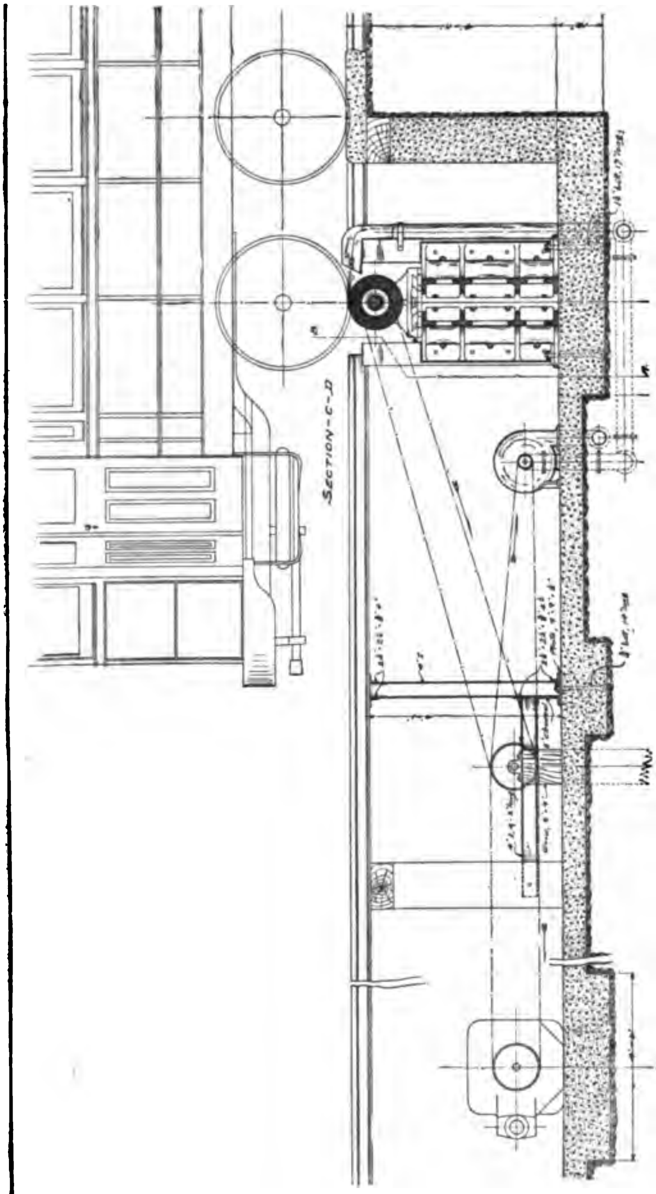


FIG. 162.—Wheel Grinding Device with Pump for Exhausting Dust.

least likely to cause damage in this location. In the design of the one shown in Fig. 162 an attempt has been made to exhaust the dust and discharge it through the blower and pipe, delivering it at some outside point where it can do no harm. Next the blacksmith shop could be the iron storeroom, in which is iron and steel, and all such supplies as wheels, axles, brake shoes, spare motors, and trucks, and other material too heavy to be handled in the general storeroom. Both the blacksmith shop and the iron storeroom should have one shop track each. Back of Building A should be a lumber storage yard, with a brick building for a dry kiln, about opposite the boiler and engine room. Space should be reserved at convenient places outside Building B for storage of scrap, as old trucks and wheels, springs, etc. This arrangement and size of shop has been selected for a road of about 200 cars, and dimensions would be increased or decreased to meet the number of cars to be served. The principal elements to be kept in view in the design of any repair shop are provision for abundance of light, fireproof construction, cleanliness, and such an arrangement of departments that the work may pass progressively to completion.

CHAPTER XI

MAINTENANCE OF INTERURBAN TRACK

A VERY few years ago, when interurban roads first came into being, the question of maintenance of way was apparently forgotten by some roads. Those who thought about the matter at all seemed to have the impression that the track would care for itself, except in case of a washout, or a wreck, and contented themselves by an occasional inspection, and cutting the weeds when they became troublesome. Most managers in those days must have known approximately the amount of labor expended on track by the steam roads, and how the opinion was formed that interurban track would require only about 10 or 20 per cent. of the other is a mystery. To be sure the light weight and low speed of the cars did not impose the wear and tear on the track that steam trains do, and it is evident that the increasing weight and speed of interurban cars finally forced attention to the care of the track, and the necessity for better conditions, if the higher speeds were to be employed.

On steam roads the life of rails is said to be about 15 years. This does not mean that they are worn out, for they are nearly always relaid on branch lines, or sidings. The fact is that most steam roads in the past have felt compelled to relay their main lines with a heavier rail in less than the time mentioned, sometimes in 10 years, on account of the increasing weight of the rolling stock, for which the former rails were too light. The life of the rails of an interurban road is a question. It has been estimated at 20 years, but it may be longer. Probably no interurban road has worn out its rails as yet, except on sharp curves. On a basis of 20 years, the cost of renewals per mile per year, for the 70-pound rail, would be 5 per cent., or about $165.00, though it is doubtful if this figure has yet been included in the cost of interurban track maintenance. The life of ties is a decidedly variable one, for one tie may last twice as long as its neighbor. It is fair to assume that 6 per

cent. of the cost is sufficient for renewals in interurban track, or about $90.00 per mile per year. Rock ballast is quite a permanent fixture and deteriorates but a small amount. $25.00 per mile per year should be sufficient.

As regards track labor, many steam roads employ one man per mile of single track, besides a foreman, during good weather, the sections being from 8 to 12 miles in length. This number is cut down about one-half in winter. It is not the custom among interurban roads to employ as many, though some of the best approach it closely. The sections of the Indiana Union Traction Company average 7 to 8 miles in length, and they employ three to five men and a foreman in summer and two men and a foreman in winter. This labor costs from $275.00 to $300.00 per mile per year. The Cincinnati, Dayton & Toledo Railway has sections 18 to 25 miles long, and employs from seven to ten men and a foreman per section in summer, and two or three men and a foreman in winter. Section men on this road work 9 hours per day at 15 cents per hour and foremen receive $1.75 per day. The wage scale varies usually between $1.25 and $1.50 per day in different parts of the country. A number of Ohio interurban roads have sections 15 to 18 miles in length, and employ an average of four to five men and a foreman in summer. Except under particularly favorable conditions this force is hardly sufficient to keep the right of way well maintained. Generally speaking, it should cost from $350.00 to $400.000 per mile per year, including tie renewals.

The employment of an engineer of maintenance of way, or a road master, should be in the interest of economy. He devotes his whole time to the care of the right of way, and by a systematic organization of his department he can invariably so direct the work as to produce economical results. Too often this department is under the supervision of some engineer or officer who has numerous other more important duties, and the care of the track is mainly left to the section foremen, who probably do the best they can under the circumstances. The life of the rail joints can be greatly prolonged by inspection and maintenance. A walk on the track of many interurban roads brings to the attention hundreds of loose joint bolts. Where is the trackwalker with his wrench and sledge? He is

an important man on steam roads, and in many localities is on duty night and day. Keeping the joint bolts tight, thereby holding the angle plates firmly in position, and the driving home of loosened spikes, is an important item of maintenance, and the expense of a man to walk a section every few days performing these duties is small. The result is a smoother, better riding track.

The care of the drainage ditches is often an important item. Oftentimes during a severe rain storm a wash-out will call attention to faulty drainage conditions which were not easily detected otherwise. Additional facilities for leading off a large quantity of water can then be provided and a repetition of the occurrence at that point be prevented. A heavy rain storm also frequently points out the fact that culverts are too small to carry off the surplus water or that they are of faulty construction. The cultivation and growth of sod on embankments is an excellent precaution against wash-outs and it gives great strength to the embankment. But the growth of grass and other vegetation on the roadbed between the ties should be prevented if practicable, for it decreases the life of the ties and is a source of expense in the cutting made necessary when it has grown tall. On some roads where built along the base of a steep, rocky hill there is sometimes danger of rocks becoming loosened and rolling on the track. In such places it is often advisable to build retaining walls of the stone in the vicinity. These are loosely built and intended simply to act as a barrier against rocks falling from above. Steam roads frequently have to resort to the above and in addition employ a trackwalker who frequently patrols the dangerous localities.

A practice often productive of good results is employed by some steam roads relative to the care of the right of way. It is the award of a prize to the section gang who have kept their section in better condition for a year than all other sections on the division. The prize usually consists of a slight advance in wages to the different members extending throughout the following year and the privilege of attaching a sign to their headquarters which announces that theirs is the "prize section." The winners are selected by the division engineers and officers of the maintenance of way department, who make careful observations at every inspection trip. The points observed

are the condition and care of the ballast, the smoothness and uniformity of the slopes, the condition of the drainage ditches, the care of the weeds and fences, and the surface and alignment of the track. In addition to these attention is given to the cleanliness and general appearance of the entire right of way. Everything which is not of use to the road is removed and no junk or tools not in use should be in sight of a train.

It is probably true that many of the above points are refinements which the average interurban manager thinks he has no time to devote to, and as he is compelled to operate his road with much less assistance in the form of division engineers and roadmasters than the steam road is, he is right to a certain extent, but it is reasonably sure that more attention will be given to the matter in the future. That the effect of a well-kept right of way is to enhance the value of the property goes without saying.

CHAPTER XII

OVERHEAD LINE MAINTENANCE

Emergency Repairs

On many railway systems in the past the subject of overhead maintenance has not been given the attention it should have. The department has not been properly organized and details have been left to take care of themselves. An investigation of overhead maintenance costs in different parts of the country has shown an exceedingly wide variation, due in part to the apparently careless methods employed in classifying these costs, and to the absence of certain economies which have been introduced on some of the more important systems.

Maintenance, as applied to overhead lines, should include simply the cost of repairs made necessary by long service, accidents or damage caused by storms. This means the renewal of poles which are no longer safe, the replacement of worn-out material, as trolley wire, hangers, ears, span wire, insulators, etc. But it should not include an increase in feeder copper, or increased weight of trolley wire or such other items as are made necessary by the usual increase in traffic and consequent weight and power of new cars. Such labor and material should be charged to capital account as new equipment. It is because this discrimination is not always made that wide variations in costs exist.

Only the more important roads have organized their overhead department in a systematic manner. In these, generally, there are two classes of repairs, viz.: emergency repairs and regular repair work, the latter also including the work charged to new equipment mentioned above. Thus there are three separate accounts, the first two being really one, but separated for operating information. High cost of emergency repairs may indicate a weak or unsatisfactory condition of the overhead system, or a bad condition of trolley wheels or improper spring tension on trolley poles. Again it may show an un-

satisfactory state of the track where, as is usually the case, the emergency department includes a wrecking outfit and attends to cars which are off the track, or have met with other mishaps.

On some roads the cost of overhead maintenance is computed on a car mile basis, but this does not seem to form a suitable comparison. It is true that the number of cars passing has an influence on the maintenance cost, but the cost per mile of track seems a far better method. The total cost of operation of a road per car mile does not afford as true an indication of its financial condition as does the cost per mile of track when compared with the receipts.

The usual emergency stations in large city systems are expected to take care of about 50 miles of double track each, although this figure is subject to wide variations. The emergency station is very similar to that of a fire company, and the following gives a description of the equipment.

The building should contain stables for two horses and storage room for one tower wagon and one wrecking wagon as well as sleeping accommodations for at least 3 men. Sometimes the men sleep in the neighborhood, where they can be easily called, but one must always be in the house. Their number usually consists of two linemen, one of whom is the relief man, and each is on duty 12 hours, and off 12 hours. Wages vary in different cities, but a fair average is $2.75 to $3.00 per day each. One driver, at $1.75 to $2.50, is also included. Where a double crew is housed in one station but five men are necessary, as only one relief man is required. The pair of horses are generally used on either wagon, so if a second call comes in when either wagon is out, the nearest station in the adjoining district is notified or the nearest car house.

The equipment ordinarily carried on the wrecking wagon usually consists of the following tools and materials:

3 lifting jacks, 10 to 15 tons each.
4 car replacers.
2 crowbars.
1 set 10-inch blocks.
1 set 8-inch blocks.
1 set 4-inch blocks.
2 lanterns.

2 wheel shoes with chains.

1 hose bridge.

An assortment of heavy blocking.

Hand lines and miscellaneous ropes and chains.

Ropes as large as $2\frac{1}{2}$ inches in diameter are sometimes included, for towing cars. Also chains made of $\frac{3}{8}$-inch steel.

The wheel shoes are placed under the wheels on disabled axles, either broken, bent, or with gears jammed, and the chains made fast to the car body, thus enabling the crew to slide that pair of wheels under the car to the repair shop without further damage to the equipment. The hose bridge is somewhat new, but is now in quite general use in most large cities. They are generally long enough to allow four lines of fire hose to pass beneath them.

The tower wagon equipment consists of the following:

1 complete set of overhead repair tools.

1 bolt cutter.

Soldering outfit—charcoal or gasoline.

12 cones and caps.

12 ears.

2 trolley wire pick-ups.

1 lifting jack, 10 tons.

Rubber gloves.

Sections of trolley wire, span and pull-off wire.

2 lanterns.

In some instances emergency stations are operated by two linemen only, one of whom is always on duty. When the call comes in he drives either wagon to the point of trouble and depends on help obtained from employees on the spot to make only temporary repairs. Afterward, at a more convenient time, the regular maintenance crew make permanent repairs. In many cases, however, the full emergency crew are employed and expected to make permanent repairs at the time.

Emergency calls are all sent in over the telephone, which is connected to the company's private exchange, and usually to the local public exchange as well. The caller describes the class of trouble—wire down, car off or wreck—and name of man reporting the trouble. Certain rules are generally issued for the guidance of emergency crews. Among others, they are required to submit a daily report giving time trouble occurred,

time call was reported and time repaired, including a clear statement of the trouble, the location, and what caused it. They are also instructed, in case a person is injured, to call a physician and notify the claim department at once. Often a city fire-alarm tapper is placed in the emergency station and the crew responds to certain calls in the more populous business districts, in order to be of assistance to the firemen in caring for broken wires which may impede the latter in their work.

As stated above, owing to the custom of including new additions to overhead equipment in the maintenance charge, it is difficult to arrive at a fair average cost for maintenance only. In the New England States it may be said that the large city and suburban systems entail an expenditure of about $150.00 per mile of track per year, of which about $50.00 is labor and $100.00 material. In the cities of the Middle West there are instances of considerably lower costs, due possibly to a somewhat more substantial form of construction, owing to the more general use of heavier cars. A maintenance charge somewhat less than $100.00 per mile of track per year is not unusual. On the other hand, where certain large systems are practically undergoing overhead reconstruction, the cost will frequently rise to $300.00 where all work is charged to maintenance account.

The cost of labor and the number of emergency repair stations on certain systems is capable of considerable variation due in part to the general condition of the overhead work, and to the methods employed by the engineer or officer in charge. One such engineer was once asked if he did not think his emergency crews had to cover a very large territory, and if it was not inconvenient at times to handle trouble on the outskirts, four or five miles from the nearest station? His reply was that it was his policy to strengthen the overhead system at those points in such a manner that trouble was very unlikely to occur. It is probably possible to do this in certain cases, and, if so, it may save the expense of an additional emergency station.

On purely interurban roads the overhead maintenance cost, even though it includes signal and telephone wires which are exposed to severe storms, is usually remarkably low as compared with a city system. Here the necessity for the ordinary emergency station does not exist, for a tower car manned by

one or more linemen and men from the car house can do all that is necessary. It is true that the slipping off of a pole on a high-speed car is liable to do considerable damage in less than a minute, but the employment of trolley catchers, together with a good alignment of the wire, has rendered such occurrences comparatively rare. A yearly average cost should not exceed $40.00 per track mile, and doubtless many roads are operating at considerably less. Much depends, in high-speed lines, on the strength and stability of the overhead structure.

Inspection and Analysis of Distribution System

In analyzing distribution conditions, the questions arise, Where are the losses, and what is the best average potential the system now gives? What portion of the station output is delivered at the average distribution potential, and how much is delivered under maximum-drop conditions? Is the greatest loss in the copper or the ground return? If in the copper, is the copper now connected with the system utilized at its maximum efficiency?

The early principles used in the laying out of a copper distribution system for electric railways, when the overload protection devices in the station were not adequate to handle a short-circuit, led to cutting the trolley wire into independently fed sections, so that a breakdown on one portion of the distribution system would not affect traffic on other lines. But development of the external distribution system has not kept pace with improvements on the overload safety devices, and the individual feeder load factors are, as a rule, far below what they could be made if these feeders were interconnected through an automatic line circuit-breaker. In case of a short-circuit on any of the lines, these automatic devices, when feeding an overload into the section in trouble, will open, and thus automatically make that section independent until the trouble is remedied. When feeders are properly connected together they act as equalizers and reduce the transmission between them, and many cases are to be found where the expenditure of a few hundred dollars for automatic circuit-breakers, provided with semaphores which indicate when they are open, will obtain the feeding value of a considerable investment in copper.

It would seem hardly possible that a constant could be de-

rived from an electric railway feeder, but by placing a recording ammeter in series with the feeder there will be noted a regular recurrence of current variations, and through these can be drawn a curve which will represent the periodicity of load on that feeder. If two adjacent feeders have their peaks or maximum loads coincident, the gain from connecting these together is small, and in such a case the trolley section may be changed in length, so as to place their maximum periods out of phase, so to speak, and then their connection will mutually reduce the loss between them. It must be borne in mind that, while the watts produced in the station are measured by the product of the volts and amperes, the watts loss in the distribution system is the square of the current multiplied by the resistance of the circuit through which it is transmitted. As the standby and fixed charges of the power station are large, it can produce 50 per cent. greater output at an advance of only 25 per cent. greater cost, especially if the load factor is improved, but the losses in the distribution system (if kept the same) have increased 25 per cent.

This clearly shows how necessary it is in improving the economy of the distribution system, to take advantage of every possible method, by utilizing properly the conductors we now have to their utmost earning capacity. The easiest possible method for the remedy of bad conditions is to buy more copper, and put it into use along such lines as show the greatest losses. This should only be done after using every endeavor to utilize the present copper to its greatest advantage.

One of the greatest mistakes in the electric railway business is overbuying. They have been doing this for years; one system will scrap what another system has continued to use with economical and commercial success. Many have been led to the abandonment of property, which still exists in the capital account of the company, by arguments and conclusions often based on false and pernicious assumptions. Early in the art certain defects or derangements in the system were assigned to certain causes. The same defect is still assigned to the same inherited cause, but in reality, in many cases, the original cause has been removed and the present cause can be easily remedied.

Testing

Economical maintenance depends much on intelligent testing, and the methods of locating and determining the relative losses in the system are of great importance. In transmission losses it is essential to find the average and maximum loads on feeders, individually; where these losses occur in distribution under actual working conditions; what portion of the losses is in the copper, and what portion is in the ground-return system, and what is the cost per annum of these losses.

In the station the loads are found by an autographic record of feeders taken during different periods of loading. On the line they may be taken by an autographic test car. The data

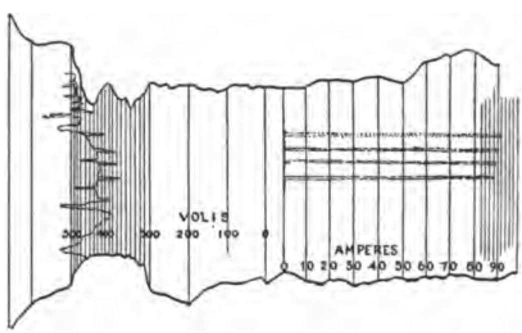


FIG. 163.—Autographic Test Record.

obtained by running over the line with such a car include the actual variation of the voltage on the line while the system is in operation, as shown on the broken line at the left in Fig. 163. In order to find the total transmission loss a load of 100 amperes is assumed. It will be seen that this will produce a greater drop on the voltmeter. Suppose the voltage before the added load was 500, afterward it was 450, then the 50 volts difference divided by 100 amperes will give .5 of an ohm for the total transmission resistance. Again, suppose the lowest voltage observed was 400 volts, then the drop on the system corresponds to a load of 200 amperes at this point. So, knowing the transmission resistance and the lowest voltage readings, we can immediately determine the feeder load which is responsible for the losses on the feeder at the point of test.

In this test we have two losses combined, the copper and the ground-return losses. We can find the copper resistance by several different methods. One, by calculating the copper resistance to the point of test, and another, by testing the system while out of service with a voltmeter. In this method the feeder to be tested is given a known load and any other feeder from the power station which has no load is used as the pressure wire back to the positive bus. This gives the drop in pressure over the loaded feeder which, divided by the current it is carrying, gives us the resistance of the copper feeder to the point of test. Then the difference between the total trans-

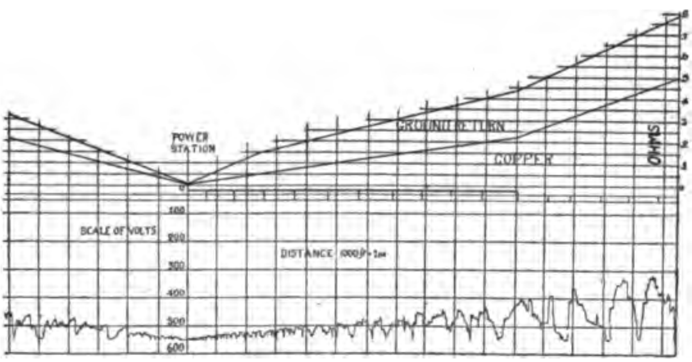


Fig. 164.—Diagram Showing Transmission Resistance and Losses.

mission resistance as found above, and the copper resistance, is the resistance of the ground return.

A graphic method of showing transmission losses is given in Fig. 164, and a diagram of the feeder is laid out, the copper losses being indicated by the length of ordinates at the different points of test. The total transmission resistance is indicated on the same ordinates at the same points. The lower area gives the copper losses and the upper area the ground-return losses, the location and amount of these losses are in this way graphically indicated. From this diagram, in connection with the feeder-load diagram, the cost of the losses per annum of a feeder while under operating conditions can be determined, as well as its efficiency compared with other feeders on the system. By comparing it with other feeders on the same pole-line, it can be found out which feeders can

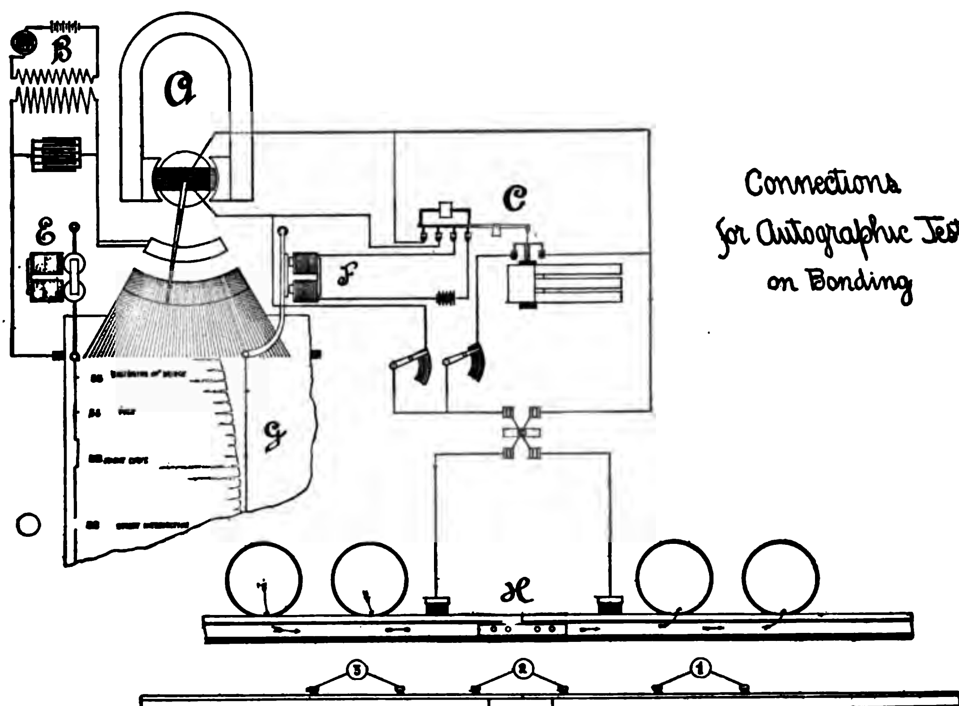
mutually assist each other to the greatest advantage by equalizing them through an automatic circuit-breaker.

In the testing of the ground-return circuit new methods have been devised, for it has become evident from the electrolysis cases in this country that while no court has yet allowed an injunction, and the question of damages has not yet been decided against the railroad company, the maintenance of the bonding of the track has been given great weight by the court, and if negligence can be shown here, damages may in the future be awarded. So it may become necessary to produce a record of the actual physical condition of every bond on the road, in order that isolated cases might not be presented to the court as a true criterion of the existing conditions. The problem is as follows: That the joint should be measured accurately in less than one-thirtieth of a second; that the sensibility of the instrument should be that of a Weston milli-voltmeter, that this instrument should be protected by an automatic device working quicker than the instrument, to cut it out of circuit when the potential exceeded that of the calibration of the instrument; that such conditions should also be marked on the record; also that every movement of the hand of the instrument should be reproduced on the record without any interference with the sensibility of the instrument.

Fig. 165 is the diagram of the connections of an instrument which was devised some three years ago, and has since made a record of over 8,200 miles of track, and tested and recorded over 2,600,000 bonds, over a ton of paper having passed through the machine in making these records. This is the recorder that is now on the Herrick autographic test car "B," which last year ran over 86 per cent. of the roads in Connecticut, and 89 per cent. of those in Massachusetts.

In order to produce this record the drop along the rail was taken by means of two steel brushes shown at "H." It has been found that the composition of the steel in these brushes must be of nearly the same composition as the rail, otherwise there will be a thermo-electric effect when taking pressures on a dry rail. The brushes are four feet apart, and it will be seen in Fig. 165 that in position No. 1 we get a drop across 4 feet of solid rail, and in position No. 2 we get a drop across the joint, and in No. 3 solid rail again. In bond testing we cannot be

sure of having current on the rail at all times, so a low-tension current of about 200 amperes per rail is caused to flow between the two trucks of the car, produced by a local low-tension generator. The drop current from the brushes is taken first to a reverse switch and then it separates in two circuits, one going through the electro-magnetic automatic and the other through the milli-voltmeter. The milli-voltmeter circuits pass through



Connections
for Autographic Tests
on Bonding

FIG. 165.—Connections for Autographic Bond Tester.

calibrating rheostats, so either instrument can be made to work through any desired range. The milli-voltmeter circuit in passing through the automatic cut-out is brought to two mercury cups which can be bridged and the milli-voltmeter cut out when the impressed electro-motive force across the automatic is any desired amount for which the latter can be adjusted. Also at the same instant that the milli-voltmeter is cut out it closes the circuit through a magnet actuating the zero pen, and marks

on the record an open bond at the point where it occurs. The movement of the milli-voltmeter hand is recorded on paper by means of a high-tension spark, the hand forming the bridging portion of this spark circuit, and is also insulated from the milli-voltmeter movement. The spark is taken by the hand from a segmental plate and distributed to a commutator; this commutator terminates adjacent to the paper, and at the back of the paper is a plate which is the other side of the high-tension circuit. The capacity of this circuit is made such that

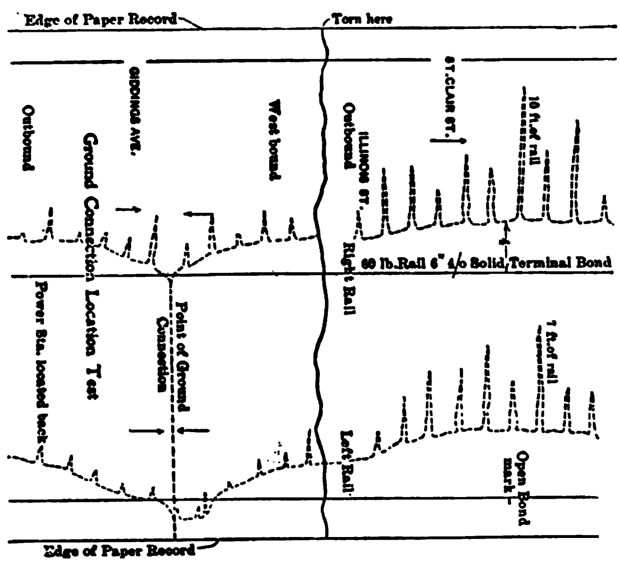


FIG. 166.—Record Made with Autographic Bond Tester.

it punctures and raises the fiber of the paper at the same time, and as all points of the commutator present the same electrical resistance to the spark, there is no dragging of the spark and every movement of the hand is reproduced on the record. The record paper moves with the car at the ratio of 120 feet of track to one inch of paper. The locations adjacent to the track are produced manually by a pen having two motions magnetically controlled, and these are made as the points are passed by the car. For a street intersection the pen is lifted from one curb to the other. Curves are offset by the signal pen from one tangent to the other, poles are indicated by a dash made when

the car is opposite the center of the pole, an electrically operated numbering machine stamps the numbers in at each station, which numbers correspond to the written list of stations and these are afterwards typewritten on the record. Both rails on the track are taken at once, but only one side is shown in Fig. 165 at G.

By using the current from the rotary, the value of which is always known, the normal current flow on the rail can be determined, and its direction. Assume with the generator on we had 200 amperes, and 10 milli-volts drop on the solid rail, when we cut off this current we found we had 6 milli-volts; 4 milli-volts is then equal to 200 amperes on the rail, or each milli-volt is 50 amperes, and consequently we have 300 amperes flow on the rail and the resistance of the rail is 6 milli-volts divided by 300 amperes for 4 feet of rail. This resistance is checked up a number of times over a route, and if we add the resistance of the total length of the line of rail to the drop found on each joint, due to the normal current flow on the rail alone, it will give us the total of the ground-return resistance, which can be checked with the results obtained as in Fig. 164.

An actual bond record, locating the defective bonding, and indicating where its improvement will produce the greatest revenue for the money expended, is shown in Fig. 166. We can also determine from this testing method where the ground returns are located, what amount of current they are carrying from the rail, and whether they are properly connected.

It is often found that outlying ground-return feeders are so connected as not to be utilized to their full carrying capacity. These connections are often broken by the repair gang, and often the load can be brought up on a ground-return feeder by more frequent taps to the rail.

In case of a foreign connection, such as a water pipe, bridge or steam track, the exact point of these connections can be located by the reversal of or a sudden drop of current on the rail at the point of connection. In a rectilinear system of rails, some lines of rails become the arteries and others tributaries for the circulation of the current back to the power station. Different power stations swap their ground-return current where the overhead system interfeeds in each other's territory. Some engineers consider that the cars have a cross-bonding effect and only em-

ploy cross-bonds in the devil strip between tracks. The cross-bond afforded by cars is only very slight, and none at all when the car is using current. As much as five volts can exist between rails while a car is rolling over them, and a recording voltmeter between a brush located on each rail will locate the cross-bonds equalizing the two tracks, and show where more cross-bonds will be effective. Open or defective bonds will cause considerable shuttling of current between the rails.

There are inherent losses in rails due to inductance set up against sudden changes in the current demand; also there is a local counter e. m. f. following a car amounting to as much as 20 volts, depending upon the speed of the car and the amount of current it discharges into the rail.

The bonding record gives all the physical conditions of the ground-return circuit, and the electrical resistance of each bond. Each mile of record is given a figure of merit, which is the percentage of the sum of open and defective bonds, to the total number of bonds in a mile. The current density on the rail is shown and the resistance of different weights can be calculated. Certain resistances of bonds compared with equivalent length of rail are considered defective; generally any bond beyond 12 feet of adjacent rail is defective, and any joint greater than 120 milli-volts is shown as open.

CHAPTER XIII

THE OPERATION OF THE MAIN REPAIR SHOP

THE general design and arrangement of the repair shop have been described in a previous chapter. Under the head of operation there are matters connected with the running of such a shop, as applied to the maintenance of equipment, which are highly important. The immense repair shops of some of the steam roads are run very much in the same manner. Their system of shop orders, requisitions for material, and method of timekeeping, etc., have been reduced to simple forms which make it easy to keep suitable records of the cost of maintenance. In some shops the piece-work system has been introduced and met with success, while many labor-saving devices have aided in reducing the cost of repairs to locomotives and cars, per mile run, to the point where any noticeable variation from the average cost can be traced to its source.

The master mechanic of a certain large railroad in the Middle West introduced the piece-work system in the shop, and the men soon went out on strike—a not unusual occurrence for such a cause. This master mechanic had found his repair cost above the average, and determined to reduce it to the average without the intention of trying to outdo other shops. It was found that there were between three and four thousand different repair "jobs" on a locomotive, and the average cost of each was listed. It was proposed to the men to accept this scale with the understanding that it would not be altered for a year, and they could make as much as they pleased by increasing their efforts, but that a rigid system of inspection of their work would be put in operation. At the end of the year an amount of money, equal to what had been saved from the average cost of repairs, would be distributed among them. This proposition was accepted and proved very successful. It meant that the cost of repairs for that road was the average, the men were making considerably higher wages due to their increased efficiency, and labor troubles entirely disappeared,

which was one of the principal objects in the change. It is not intended to refer to labor troubles in electric repair shops, for happily they are few, but to illustrate how the steam roads sometimes handle their shops. Some writer, not long since, referred to a difference in the manner in which the men worked in a certain steam-road shop, and some electric shops. In the former everyone was moving, and all seemed thoroughly familiar with their work, while in the latter there was often seen a tendency to stop and wonder what to do next. This may be true in some cases, but it is not so much due to a difference in the quality of the men, as to a lack of electrical knowledge. They may be good mechanics, but their work is so intimately associated with wires, windings and other electrical conductors, that they are frequently puzzled as to the right course to pursue. Those who attend to electrical repairs are seldom the kind of mechanics needed on truck repairs. The situation is no doubt due to the very recent development of the electric-motor car, but the time will come when the men employed in the electrical repair shop will be as familiar with the different classes of repair work as are those in the locomotive shop.

In the largest electrical repair shops the piece-work system may be practicable, but it requires a very careful study to properly adjust the rate. The essential advantage of piece work is where duplicate work predominates, as in a manufacturing establishment turning out a product consisting of thousands of articles all alike. Piece work is easily applied to car building, and about all the large car builders employ it in their shops. They make it successful because they build a large number of cars and trucks which are nearly duplicates of each other. On a road using many cars, especially a double equipment for summer and winter, there is sure to be a large number which are identical, and possibly only three or four varieties. It is possible, in such a case, to arrange a satisfactory piece-work rate for all general repair work, but the rate should never be based on what it costs to do the same work by day work, for almost invariably the men can double their former wages. This produces double the work at no lower cost. The proper rate is between the latter and the day-work cost, but just where is difficult to decide. If the rate is placed too high it is necessary to reduce it, and this always has a bad effect on the

morale of the shop. The proper rate is that which enables a workman to increase his wages in proportion to his added activity, but only in a reasonable degree, for no man is supposed to work so strenuously that he has no reserve power left. The greatest evil of the piece-work system is in evidence when it becomes necessary to frequently cut prices in order to keep down the wage account, due to the increasing amount of work done. This invariably leads to the men placing a limit on their own speed, due to the fear of a cut in price if they work too fast. In the case of a rush job the effect is bad, and such a condition of affairs should never be allowed to exist, though, unfortunately, it too often does. What is known as the premium plan is sometimes successfully used. It is as follows: The men are paid by the hour, which is the same as day work, and in addition are given a premium, or a certain sum above their regular wages, for work done in excess of a certain amount. This system might be called the reverse of the piece-work plan, and makes it necessary to go as deeply into the cost of work in order to determine what constitutes a day's or an hour's work on the different repair jobs.

When a car is taken into the shop for general repairs and overhauling, it is first shifted by means of the transfer table to the inspection room. Here all removable fixtures of the car body, such as seats, window sash, doors, etc., are taken out of the car, stored conveniently near by and tagged with the car number. This is done at this time principally because it facilitates the thorough inspection to which the car is now subjected, in order to determine the exact character of the repairs necessary. They are afterward sent to the respective departments, where they are painted, varnished, or cleaned, as the case may be. This method of stripping and inspecting a car has many advantages. It places all cars in the hands of a gang of experienced strippers and inspectors, whose work is chiefly of that nature and they become expert at it. It is the regular course of procedure in car and locomotive repair work in all steam-road repair shops. The general shop foreman receives the reports of the inspectors, and personally goes over the car, making an estimate of the cost of the labor and material necessary to put the car in first-class condition. He then, upon a blank form gotten out for the purpose, gives the date the car was

last overhauled, with the cost of repairs made at that time, and his estimate of the repairs now needed. This is sent to the master mechanic for authority to proceed with the work. On receipt of the approval, a shop order is issued having a number, as well as the number of the car, and all labor done, and material furnished the car, is charged to this order number. When work is started, the car is first taken to the erecting shop, where it is jacked up, and the trucks sent to the truck shop. Then the different foremen see that the work decided upon is done, and they report the material used, with its cost, and the labor charge, to the general foreman. Each foreman is furnished with a description of the work he is to do, as shown in the inspector's report. This is also made out on a special blank form for the purpose. There are various other blank forms used which are very necessary for the systematic operation of a shop. One is used between foremen who desire labor and material from each other's department. Another, which is of great importance, is the requisition for material and supplies from the general storeroom; also the wheel report, on which is recorded the numbers and circumferences of the wheels removed and supplied, with the date and cause of removal, etc., the wheel record giving the mileage of wheels, and the number of times ground or turned down. An armature record is also necessary, giving a report of repairs to each armature, with its number.

Unfortunately, at the present time, there is little or no uniformity among the different repair shops in the character of these records. At present each shop has a system of its own, which seems best fitted to the requirements, but the systems are so widely diversified that intelligent comparisons are well-nigh impossible. This renders it useless for the different electric roads to attempt to establish an average cost of repair work, with any degree of accuracy, as do steam roads. A good start was made to establish a uniform system of "Blanks for Shop Records and Accounts" in a report submitted at the St. Louis Convention, in 1904, by a joint committee of the American Railway Mechanical and Electrical Association and the Street Railway Accountants' Association. Although the report of this committee was never adopted by the Association, it was accepted and the committee continued.

FORM FOR TABULATING WEEKLY COST OF LABOR AND MATERIAL USED IN MAINTAINING EQUIPMENT.

SCHENECTADY RAILWAY CO.

COST OF MAINTENANCE FOR THE MONTH OF..............190

Working Order No.	Working Order Nos. Covering	Week Ending		Week Ending		Total Labor	Total Material	Total Labor and Material
		Labor	Mater'l	Labor	Mater'l			
R 30 M	Labor and Material, Maintenance Fuller St. Barn							
R 35 M	" " " McClellan St. Barn.							
R 60 M	" " "Air Comp. McClellan St. Barn							
R 61 M	" " " " Fuller St. Barn..							
R 90 M	" " Repairing Fenders..............							
R 090 M	" " " Express Cars							
R 91 M	" " Painting Car Bodies							
R 091 M	" " Repairing Sand Boxes...........							
R 92 M	" " " Car Bodies...........							
R 092 M	" " " Electric Heaters							
R 93 M	" " " Registers							
R 093 M	" " " Electric Head-lights...							
R 94 M	" " " Air Brake Equipment.							
R 95 M	" " " Car Signs............							
R 095 M	" " " Trucks Dam. in accid't							
R 96 M	" " " Trucks, Maintenance.							
R 096 M	" " " Car Bodies, dam. in accid't							
R 97 M	" " " Snow Scrapers on Cars							
R 097 M	" " Turning Down Flat Wheels							
R 98 M	" " Repairing Emergency Brakes....							
R 99 M	" " Inspecting Trucks..............							
R 100 M	" " Repairing Motors							
R 101 M	" " " Car Wiring							
R 102 M	" " " C-8 Controllers.........							
R 0102 M	" " " Armature Liners......							
R 103 M	" " " K-Controllers							
R 104 M	" " " Contactors & Rev. Switches							
R 0104 M	" " " Elec. Equip. Dam. in accid't							
R 105 M	" " " Trolley Poles							
R 106 M	" " " Armatures							
R 109 M	" " " Elec. Equip. Express Cars							
R 120 M	" " " Snow Plows							
R 130 M	" " " Shop Tools, Etc.......							
R 260 T	" For Cleaning Lamps, Lanterns, H'd-lights, etc.							
R 261 T	" Getting Crippled Cars to Shop.................							
R 262 T	" Cleaning Cars							
R 263 T	Wages, Barn Sweepers							
R 264 T	" " Foremen							
R 265 T	Labor, Inspecting all Elec. Equip. of Cars							
R 266 T	" For Oiling Cars at McClellan St. Barn							
R 267 T	" " " " Fuller St. Barn							
R 270 T	Furnishing Incandescent Lamps for Passenger Cars							
R 271 T	Material for Cleaning Cars.........................							
R 272 T	Sundry Car Service Supplies, Lanterns, Etc..........							
R 280 T	Labor, Getting Derailed Cars on Track							
R 283 T	Heating McClellan St. Barn; also Cost of Coal... ...							
R 284 T	" Fuller St. Barn; " " "							
R 285 T	Sundry Car Barn Supplies, Fuller St. Barn							
R 286 T	" " " " McClellan St. Barn							
R 287 T	Labor & Material, Maintenance, Air Comp. 420 State St.							
R 290 T	Handling Sand for Cars............................							
R 27 T	All Lubricants for Cars............................							

Cost of Labor, Car Cleaning Only, per Month.......		Total Car Miles per Month.........	
Cost of Labor, Car Cleaning per 18 Hour Car...................		Total Car Hours per Month.........	
Cost of Labor & Material, including Car Cleaning per 18 Hour Car.		Local Cars, Average per Day.......	
Cost of Labor & Material, Not Including Car Cleaning per Car Mile.		Albany " " " "	
		Troy " " " "	

Mr. Richard McCulloch, formerly manager of the Chicago City Railway, in a paper before the American Street Railway Association, gives some very interesting figures on the cost of repair work while operating about 500 motor cars. Among these figures is given the cost of dismounting, inspecting, cleaning, and overhauling the trucks, motors and electrical equipment of double truck, four-motor cars as $8.00 and of single truck, two-motor cars, $4.00. The average maintenance of one car per annum is $187.00 and per car mile $0.0054. Average cost of car painting per car, per year, $25.69, which represents touching up and revarnishing chiefly. The cost of performing various operations follows.

Machine Shop—Cost of Performing Various Operations.

Labor in turning axle, cutting key-way, boring wheels and pressing wheels on axle.

(a) 30-inch wheels fitted on 4-inch axle for No. 49 Westinghouse motor.	
Turning axle, 2½ hours at 25 cents	$ .63
Cutting key-way, ½ hour at 30 cents	.15
Boring and fitting wheels, ½ hour at 33 cents	.16
Pressing on wheels, ½ hour at 20 cents	.10
Total Cost	$ 1.04
(b) 33-inch wheels fitted on 4½-inch axle for G. E. 67 motor.	
Turning axle, 3½ hours at 25 cents	$ .88
Cutting key-way, ½ hour at 30 cents	.15
Boring and fitting wheels, ½ hour at 33 cents	.16
Pressing on wheels, ½ hour at 20 cents	.10
Total cost	$ 1.29
Cost of trolley wheels.—Material.	
100 brass castings, 3 pounds at 15 cents	$45.00
100 graphite bushings at 10 cents	10.00
Labor.	
Boring and facing 100 wheels, 4 hours at 30 cents	1.20
Turning 100 wheels, 2 hours at 30 cents	.60
Pressing in bushings, 1 hour at 15 cents	.15
Total cost of 100 wheels	$56.95
Cost per wheel	.57
Re-bushing and turning old wheels.—Material.	
100 bushings at 10 cents	$10.00
Labor.	
Pressing out old bushings, 1 hour at 15 cents	.15
Pressing in new bushings, 1 hour at 15 cents	.15
Turning, 2 hours at 30 cents	.60
Total cost for 100 wheels	$10.90
Cost per wheel	.11

Electrical Repair Department—Cost of Performing Various Operations.

Note—These estimates are based on the following cost prices:
No. 4 d. c. c. magnet wire, 15¾ cents per pound.
No. 5 and No. 6 d. c. c. magnet wire, 16 cents per pound.
No. 6 square d. c. c. magnet wire, 21¼ cents per pound.
No. 7 d. c. c. magnet wire, 17 cents per pound.
No. 0.220 asbestos covered wire, 19 cents per pound.
No. 9 d. c. c. magnet wire, 18 cents per pound.
No. 10 d. c. c. magnet wire, 18 cents per pound.
No. 11 d. c. c. magnet wire, 18¼ cents per pound.
Scrap magnet wire for re-insulating, 10 cents per pound.
Commutator bars, 22 cents per pound.
Amber mica, 95 cents and $2 per pound, according to size.

	Labor	Material	Total
Rewinding No. 12 Westinghouse armature.....	$5.00	$12.73	$17.73
Rewinding No. 49 Westinghouse armature.....	5 30	14 31	19.61
Rewinding No. 3 Westinghouse armature......	6.46	13.75	20.21
Rewinding G. E. 800 armature................	11.57	18 27	29.84
Rewinding G. E. 67 armature.................	6.71	18.60	25.31
Rewinding No. 5 Walker armature	7.89	16.09	23.98
Manufacturing one No. 12 Westinghouse field coil (new wire)............................	0.95	8.17	9.12
Manufacturing one No. 12 Westinghouse field coil (old wire re-taped)	1.19	6.94	8.13
Manufacturing one G. E. 67 field coil (new wire)	0.79	10.07	10.86
Manufacturing one G. E. 67 field coil (old wire re-taped)	1.12	6.78	7.90
Manufacturing one No. 12A Westinghouse field coil (new wire)	0.88	12 81	13.69
Manufacturing one No. 12A Westinghouse field coil (old wire re-taped)	1.47	7.95	9.42
Manufacturing one No. 3 Westinghouse field coil (new wire)............................	0.97	8.63	9.60
Manufacturing one No. 3 Westinghouse field coil (old wire re-taped)	1.47	6.95	8.42
Manufacturing one No. 5 Walker field coil (new wire)................................	0.86	9.15	10.01
Manufacturing one No. 5 Walker field coil (old wire re-taped)	1.10	7.82	8.92
Manufacturing one No. 49 Westinghouse field coil (new wire)............................	0.86	8.10	8.96
Manufacturing one No. 49 Westinghouse field coil (old wire re-taped)	1.19	6.64	7.83
Manufacturing one G. E. 800 field coil (new wire).....................................	1.08	11.70	12.78
Manufacturing one G. E. 800 field coil (old wire re-taped).............................	1.45	9.85	11.30

	Labor	Material	Total
Manufacturing No. 12 Westinghouse commutator	$1.51	$13.15	$14.66
Manufacturing No. 12A Westinghouse commutator	1.59	22.57	24.15
Manufacturing G. E. 800 commutator	1.59	11.66	13.25
Manufacturing No. 5 Walker commutator	1.51	8.57	10.08
Manufacturing No. 3 Westinghouse commutator	1.51	11.55	13.06
Manufacturing No. 49 Westinghouse commutator	1.72	19.88	21.61

Details of winding G. E. 67 armature—Material.	
65 pounds No. 9 magnet wire at 18 cents	$11.70
6 square feet No. 20 manila paper	0.04
45 yards No. 4 sleeving	0.32
234 yards ¾-inch linen tape	0.94
3 pounds No. 16 band wire	0.58
1¼ pounds solder	0.25
4 square feet fiber	0.11
2 pounds India mica	1.76
1½ pounds ¾-inch friction tape	0.36
2 pounds 1¼-inch friction tape	0.49
1½ square yards drilling	0.11
3 quarts voltalac	1.12
3 square yards No. 10 empire cloth	0.78
½ pound glue	0.04
Labor—	
Winding armature coils, 2½ hours at 0.175 cent	0.44
Gluing armature coils, 6 hours at 20 cents	1.20
Taping armature coils, 2½ hours at 15 cents	0.37
Cutting, tinning, dipping coils, 3 hours at 17 cents	0.51
Stripping, rewinding, soldering armature, 12 hours at 0.275 cent	3.30
Turning commutator, ½ hour at 0.275 cent	0.14
Banding armature, 5 hours at 15 cents	0.75
Total cost of rewinding armature	$25.31

Details of winding G E. 67 field coil—Material.	
48 pounds 0.220 asbestos covered wire at 19 cents	$9.12
1 square yard No. 10 empire cloth	0.26
1½ square yards sheeting	0.10
1½ pounds friction tape	0.37
1 pint Monarch insulating paint	0.15
1½ square feet No 20 manila paper	0.01
¼ pint P. & B. paint	0.06
Labor—	
Winding coil, 1 hour at 17½ cents	0.17
Insulating, 2½ hours at 27½ cents	0.62
Total cost of field coil	$10 86

The wages paid in this shop are as follows :

	1902 Cents per hour			1903 Cents per hour		
Machinists	27½		30	30	33	
Machinists' helpers	17½		20	20	22½	25
Blacksmiths	27½		31⅝	30	33	
Blacksmiths' helpers	19⅝			22		
Brass molders	25		30	25	30	
Armature winders	25	27½	33	25	27½	33
Electrical helpers	10	15	18	10	15	18
Tinners	26¼		27½	26¼		27½
Harness makers	25			25		
Wood mill workers	20	25	27½	20	25	27½
Cabinet makers	25	27½		25	27½	
Car washers (paint shop)	17½			17½		
Rough painters (paint shop)	20	22½		20	22½	
Varnishers and finishers	25			25		
Stripers and letterers	27½			27½		
	Rate per day of 10 hours 1902			1903		
Car house repairers	$1.75	2.00	2.25	$1.92½	2.20	2.47½

Shop Kinks

This title, while it cannot be found in a standard dictionary, has nevertheless been in use for many years by men employed in the mechanical trades. Briefly it means new, unusual and simplified methods of doing certain work common to a number of shops. Master mechanics and others are continually devising means for conducting certain work at less cost of labor by utilizing various new tools and jigs. Such methods can only be discovered by continued and careful study of the conditions surrounding the work in each shop. It is not the intention to suggest any new "kinks" here, but to describe and illustrate a few which have been put into use during the past few years, relating only to methods employed in electric-railway repair shops and car houses.

For facilitating the movement of cars or motor trucks from one department to another about a shop, in connection with the transfer table, some shops locate a controller and rheostat in a central position near the table, and by means of long leads utilize the motors themselves to move their own trucks or cars to and from the table. Others use a motor truck fitted up like a small locomotive with a controller, which receives current from a contact rail imbedded 2 inches or 3 inches deep in the

concrete floor, by means of a small shoe. This runs in the slot about two inches wide in the floor, and the contact rail is thus protected, it being only necessary to sweep out the slot should dirt collect in it. This method is of great utility in moving cars or trucks about.

That armature shafts at the bearing fit will be of various sizes is inevitable, and in rebabbitting a bearing the boring in a lathe, or scraping to the fit, can be avoided by keeping in stock a number of well-made mandrels, or arbors, each slightly different in size. If the mandrel nearest in size to the shaft to be fitted is used, and the babbitt well poured, a fit will generally be obtained which seldom requires scraping. This method is a great saver of labor.

Where many duplicate repair parts are required on trucks, motors or controllers, interchangeability is of prime importance. When it is economy for the railway to manufacture these parts for themselves, as is often the case, many of the methods of the original manufacturer could be followed with profit. This means that all machine work done on raw material, as castings, rods, levers, or hangers, should be carried out with the aid of standard jigs or templates. The drilling or finishing of a piece, destined to replace another which has worn out, without a jig or other guide, requires the closest measurement, and the labor of a skilled machinist. The employment of a jig depends upon the number of such parts required in a given time, as the cost of the jig is often considerable, and must be weighed against the cost of the skilled labor. Its great advantage is the certainty that parts will interchange without refitting, and that unskilled labor may be employed in their manufacture.

Fig. 167 illustrates one manner of building a jig for drilling brake hangers. One end of the hanger is centered by hand and drilled in the ordinary way. The hanger is then placed in the jig and the pin dropped through the drilled end. The other end is then brought under the drill, clamped in position, and the drill, guided by a steel bushing, bores the other end. It can be easily seen that any number of hangers drilled in this manner will have the distance, center to center of holes, absolutely alike. The other holes in the jig for the pin are for use with hangers of different lengths. In the manufacture of small

pieces from sheet metal, as controller finger springs, an opportunity is often found for the use of punches and dies, and when such articles are needed in quantities their cost may be greatly reduced. Special chucks and jigs for turning and drilling controller cylinder rings may also be used to advantage. It may not be fully understood, on small roads at least, that an old, worn-out controller can be rebuilt and made as good as new, at small cost, and usually without ordering the new parts from the manufacturer.

The swing links supporting the bolster of a truck carry the

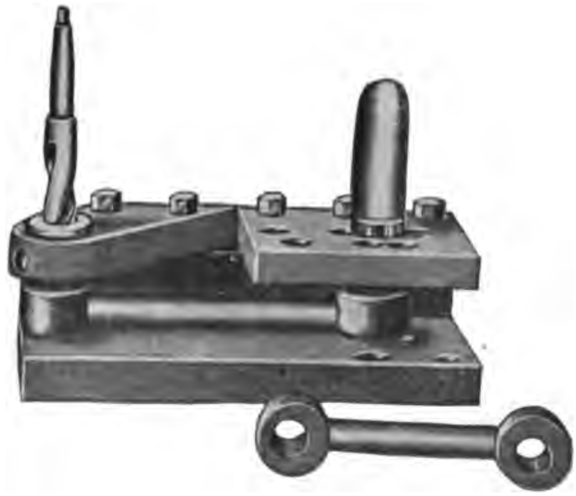


Fig. 167.—Jig for Drilling Brake Hangers.

weight of the car body, and while the strain is wholly tension, the wear on the pin holes in the ends is considerable. Instead of replacing them with new links the plan employed in Fig. 168 has been used with success. The sketch explains itself. The holes are originally drilled large enough to take a hardened steed bushing, the inside diameter of which is the proper size for the pin. The bushing will last much longer than the hole without it, and when it does wear a new bushing is easily substituted.

Some roads make their own trolley wheels, but this is a case where the market price should be carefully considered, for competition has brought the price down so that few roads can make

them any cheaper. Opinions differ as to the best mixture, but manufacturers have made many experiments which it would be a waste of time to repeat. As recently pointed out, the turning up of a trolley wheel so that it is in perfect balance has the effect of greatly prolonging its mileage.

Most roads rebuild their own commutators, which nearly always reduces the expense. In this work the most important special tool is a chuck for assembling and holding the segments in their proper form so that the interior can be turned and the permanent clamping shell fitted in place and insulated. A number of commutator jigs are in use, and one of the best consists of a heavy solid-steel ring with rows of inwardly projecting set screws. These set screws bear on an in-

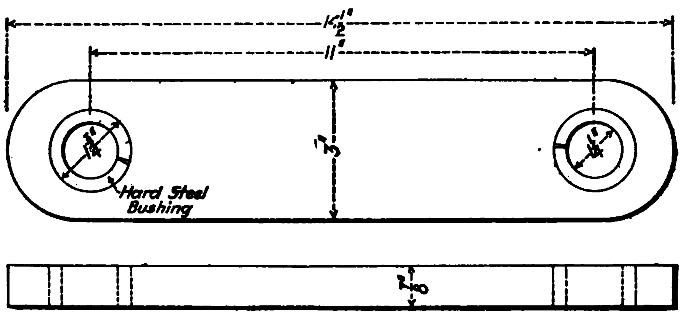


FIG. 168.—Method of Using Replaceable Hardened Bushings in Bolt Holes of Swing Links.

ner expandable ring or chuck consisting of a number of steel segments which interlock with each other around the circle through tongues and grooves. This binds the commutator tightly and holds each segment in place.

After the commutator bars are set up, the chuck containing them is placed on a hot table, or in an oven, and thoroughly heated through, and the set screws are again set up tight. This forces out all the plastic material used in the insulation, and after the commutator has been turned for the end rings it can be taken out of the chuck or jig and the assembled commutator will ring when tapped with a hammer. This precaution will tend to prevent the bars working high when heated in operation.

The rewinding of fields and armatures is carried on by all

roads except the smallest. A reduction in maintenance expense is sure to result where the best facilities, and experienced men, are provided for carrying out this work. Winding should always be done in a room by itself, which is kept clean, and never in a corner of the machine shop where it would be exposed to metallic dust, and where such dirt could soil the hands of the men. The wire of burned-out field coils is sometimes cleaned of the old insulation and reinsulated by taping machines. Opinions differ as to the advisability of this, for the

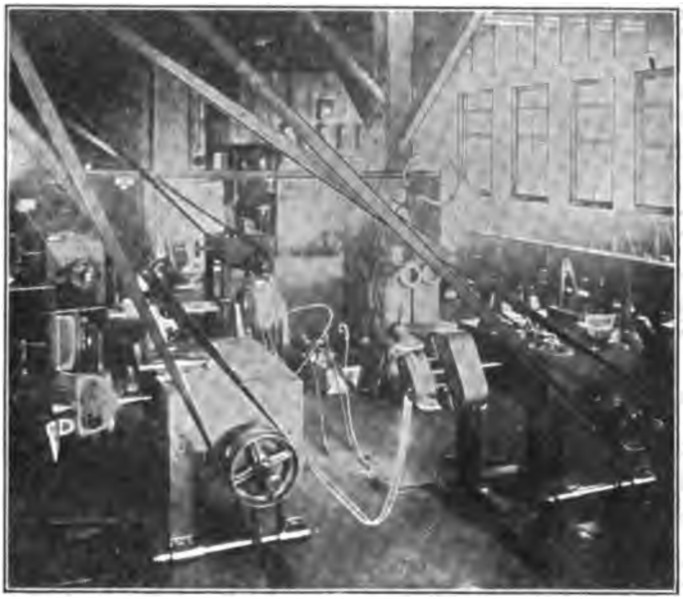


Fig. 169.—Coil Winding Machines.

rewound fields nearly always show a higher resistance than the standard, due, in part, to the stretching and annealing the wire has undergone, which reduces its diameter. The use of such field coils, paired with those of standard resistance, has caused trouble, sometimes of considerable extent, by the unbalancing effect between motors under the same car.

Fig. 169 is a view of a winding room, showing field-coil winding machines in the foreground. These machines drive the form holding the coil by means of a worm shaft and gear, and are started and stopped by a foot lever. Armature coils wound

on the usual forms should be kept in stock for the various styles of armatures in use.

When armature coils are to be removed for renewal of defective coils and their insulation is brittle, the latter can be softened by immersing the entire armature in a tank of raw linseed oil for several hours. The armature can be lowered into the oil, pinion end down, by a tackle and then raised and

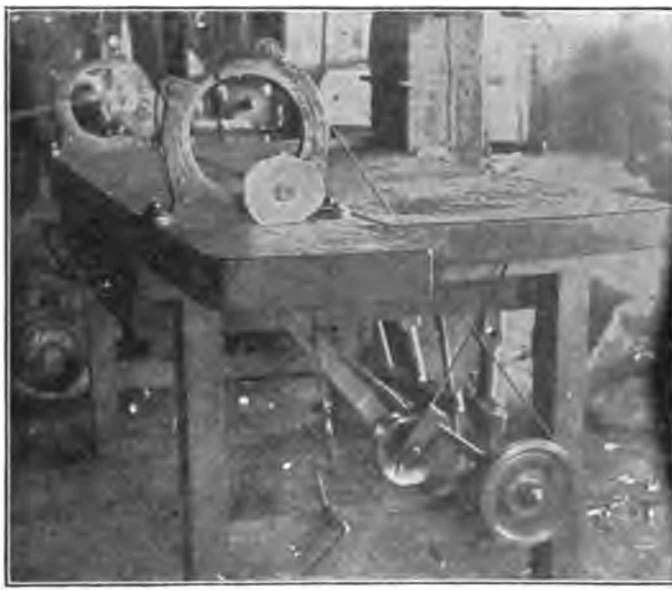


FIG. 170.—Tape Winder.

allowed to drain. The coils can then be bent as if new, as this renders the insulation very pliable.

The labor of rewinding tape on armature coils by hand can be greatly reduced by a power winder. Several shops have their own designs for these tape winders. Fig. 170 shows the general form in use, the principle of which is to introduce the coil inside a revolving ring on which is mounted the roll of tape, and the latter is carried around the coil to be taped by the machine. With experience 20 armature coils can be double-taped per hour with this machine.

Fig. 171 shows a home-made tool for handling a pair of wheels on the axle. It is universally used in all steam-road

shops and should be found in all electric-car shops. Being made of hard wood it is easily constructed. The distance from the step to the lower end is such as to lift the wheel from ¼ to ½ inch off the floor.

When it is not desirable in car washing to allow the water to run on the ground or floor, the use of two troughs and the tub shown in Fig. 172 is an ingenious way to avoid it.

For certain testing purposes the usual portable lamp bank, consisting of five lamps in series, mounted in wall sockets on a

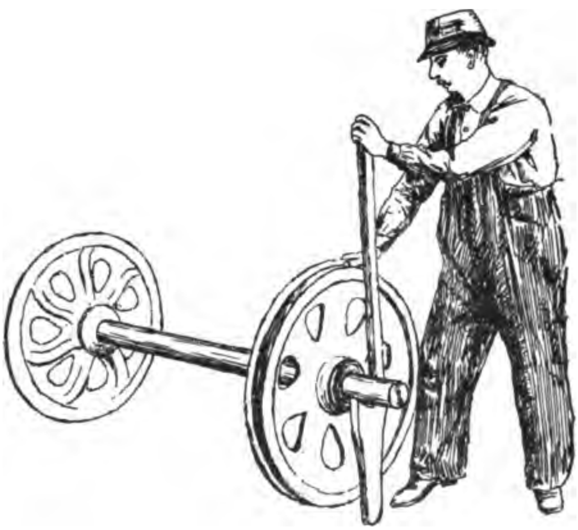


FIG. 171.—Home-made Tool for Handling Pair of Wheels on the Axle.

board can be improved upon. The constant breakage of the lamps causes a considerable loss of time and expense in replacing them. The idea seen in Fig. 173 is much better. Two 300-volt lamps in series mounted in a wooden frame wide enough to protect the lamps if it lies flat on the floor. Wire netting on each side would be a further protection.

Car circuit-breakers are seldom tested as often as they should be, to be kept in good operative condition. One reason for it is that there are no simple methods provided for making the tests in the car house. Ordinarily one would open the circuit at the breaker and insert an ammeter; then set the brakes tight and open the controller until the required current flowed;

if the breaker does not open it should be opened by hand and adjusted for a smaller current This method, while sometimes used, is not recommended on account of the strain on the apparatus, which gets enough of such treatment in service without repeating it in the tests.

Fig. 174 shows a simple arrangement for making such tests, which eliminates all danger to apparatus. A water rheostat

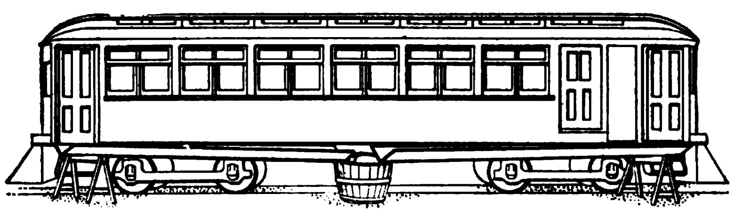


FIG. 172.—Car Washing Outfit.

is easily constructed of an oil barrel which is nearly filled with salt water. An iron plate or an old casting is attached to a wire connected to the trolley wire or feeder and arranged in some simple manner, as a rope and a pulley, so that the casting

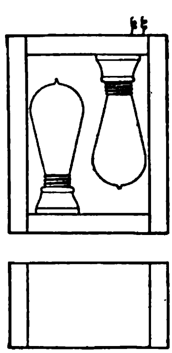


FIG. 173.—Portable Lamp Bank.

can be lowered into and lifted from the water in the barrel. Another wire has a piece of metal attached which is allowed to lie in the water at the bottom of the barrel. This wire passes through an ammeter, or its shunt, and thence to the trolley pole of the car to be tested. The trolley wheel must not be in contact with the main trolley wire, but can be

placed as shown on a short piece of false trolley wire to which the test wire is connected. The car wiring and motors should be shunted by a short "jumper" wire with a small copper plate soldered to each end. These plates are placed between the top and bottom fingers of the controller and the segments. A second circuit-breaker may be placed in the test circuit as

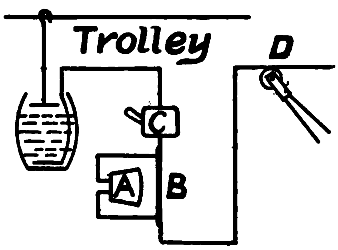


FIG. 174.—Connections for Testing Circuit Breakers.

shown at "C," for precaution, if desired. Any current wanted can now be obtained by lowering the top, or positive, plate into the water. With this outfit set up in a convenient place in the shop, or car house, a breaker can be tested in a very few minutes.

Armatures are not very convenient things to move about a

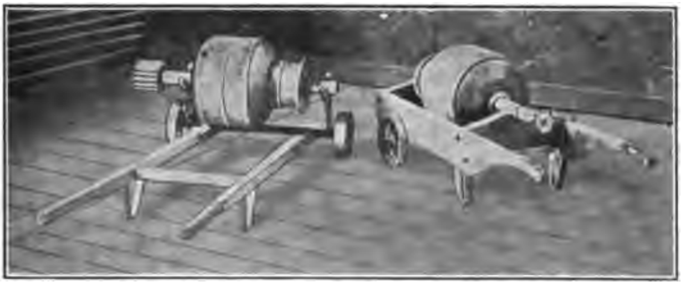


FIG. 175.—Two Forms of Armature Trucks.

shop for they are not only heavy, but care must be used to protect the winding and commutator from contact with other objects. It is hardly safe to handle them, except by means of the shaft. To this end several styles of armature trucks have been devised, and are in use in various shops. These may be divided into two classes: those in which the armature has to be lifted

up and placed by hand, and those which are self-loading, or which pick up the armature from the floor and carry it by the shaft. Fig. 175 shows two forms of armature trucks. The one on the left is adapted to pick up an armature by the shaft on lifting the handles almost to a vertical position, after the manner of an ordinary hand truck used for freight.

Fig. 176 illustrates another type which is designed to pick up the armature. The sketch shows its construction and method of handling clearly. The gauge or distance between the wheels

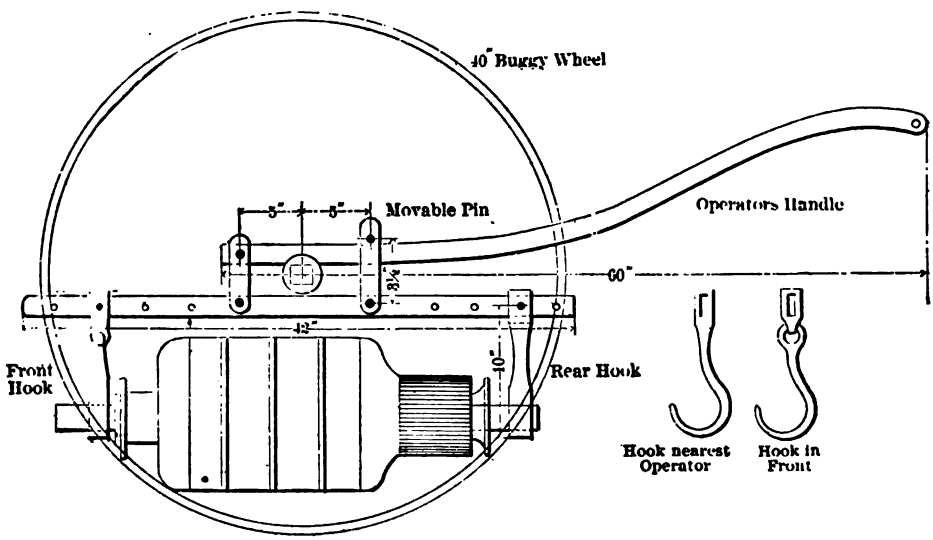


FIG. 176.—Armature Truck Designed to Pick up the Armature.

is 20 inches. Several modified forms of this truck are in use. The most common form has an axle with an upward arch, thus allowing the use of wheels much smaller in diameter. In this form the handle is forked and solidly attached to the axle each side. The carrying bar is in the center above the axle and attached to it, while the rear end of the bar is attached to the handle where it forks. The two hooks are adjusted, and of the proper length, so that by tipping the truck one way one hook can be placed about the armature shaft, and by reversing the other hook can be placed.

The home-made derrick car, an outline of which is seen in Fig. 177, will be found to be of great convenience in handling

special work or heavy freight belonging to the company, if no better facilities have been provided. It may be operated by a suitable windlass driven either by hand or a motor. All the mechanical details are not shown but are easily worked out. The bottom of the boom is attached to a loose ring on the mast. This ring should be heavy and made of wrought iron. Two pins or trunnions on opposite sides might be screwed into the ring to take the fork on the boom. This fork could be welded into the end of the boom. The cap on top of the mast carrying

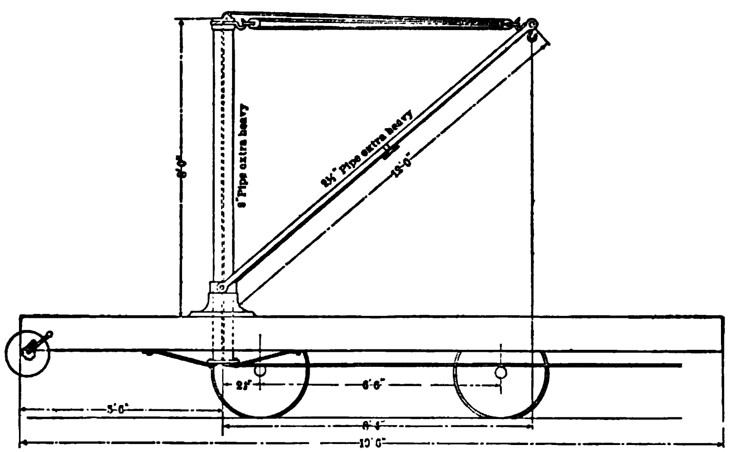


FIG. 177.—Home-made Car Derrick.

the guide pulley and the hook for holding the block and fall could be made to fit over the top of the mast and should rotate about it. The cap at the bottom of the mast, carrying the lower guide pulley and braces for the mast, is stationary. The ring for carrying the hooks at the outer end of the boom should be formed on the end of a wrought-iron rod which is welded in the end of the boom. The mast and boom are made of extra heavy wrought-iron pipe. The mast should be firmly braced both beneath the car and by a heavy cast-iron base plate on the floor, as shown.

The operation of unloading new cars from railroad flat cars is often attended with inconvenience and unnecessary expense. In the majority of cases it is accomplished by some makeshift devices accompanied by danger of damage to the car. If the

steam road has a connecting track into the shop yard of the electric road the following simple apparatus can be erected on the property of the company and becomes a permanent fixture. If it can be erected temporarily on the property of the steam road or others, it should soon pay for itself, as it is said to cost less than $100.00.

It consists of four upright posts, 12 inches by 12 inches, placed two on each side of the track, with sufficient side clearance to pass all steam railroad cars. The posts are about 18 feet high, and a 12-inch I-beam 20 to 25 feet long is framed into the top of each pair of posts, parallel to the track. The posts are tied together across the track at the tops by means of tie rods inclosed in pipe thimbles or spacers. These pipes are also fastened to the posts by flanges and lag screws. On each I-beam there are two 4-ton chain hoists which are suspended from rollers by a U-iron. The connection between the lower hook of the hoist and the truck consists of a flat bar of iron, 1 inch x 4 inches, bent into the form of a square hook, to fit the side of the truck, with an eye at the upper end. Of course the strength of the whole apparatus must be proportioned to the weight of the cars to be handled.

One road using this apparatus in unloading a large number of cars, with a gang of six men, found the average time required to unload a car was but 10 minutes, and this included the removal of both the motor car and the flat car, leaving the space clear for the next.

At times it is necessary to cut circular holes about 10 inches diameter through sheet-steel dashes for headlights. This is a somewhat difficult operation if a special tool for the purpose is not at hand. Such a tool has been made as follows: A wrought-iron forging about 2 inches square and 12 inches long is arranged to carry near its ends two small cutting wheels similar to those in a pipe-cutter. Midway between the wheels the forging is carried on a spindle $\frac{3}{4}$ inch diameter threaded at both ends and with a collar $\frac{1}{2}$ inch thick and $2\frac{1}{2}$ inches diameter in the center. Extension pieces are bolted to each end of the forging to be used as handles to turn it. A circular iron plate or washer $\frac{3}{4}$ inch thick and 12 inches diameter with a $\frac{3}{4}$-inch hole in the center is arranged to fit over the opposite end of the spindle, which is turned and

threaded $\frac{5}{8}$ inch at this end. A nut is used on each end of the spindle, one of which holds the forging firmly against the collar, and the other is back of the large washer.

In using the tool a $\frac{11}{16}$-inch hole is drilled through the dash in the center of the proposed headlight opening, the spindle is introduced from the outside and the washer held against the inside by the nut. The forging carrying the cutting wheels is then turned by hand and the nut on the washer gradually set

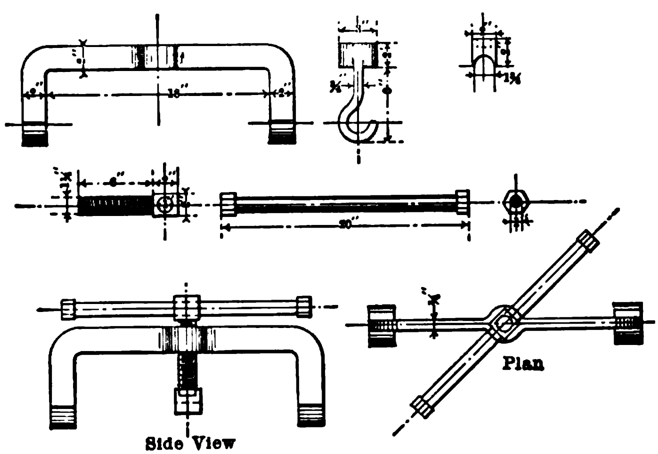


FIG. 178.—Jim Crow Bar for Straightening Trolley Pole.

up to feed the cutters. A dasher of No. 12 steel can be cut for a 10-inch headlight with this tool in about eight minutes.

A small, light Jim Crow, which is simply a miniature copy of those used in bending rails, is often of value among the tools of a shop or car house. Its special use is in straightening trolley poles and bent stanchions. It is easily carried to the top of a car and used without removing the pole. Fig. 178 shows in detail the construction of such a tool as used by a certain road.

The handling of wheels, which includes the removal of an old pair and replacing them with a new set under a car, is often a process occupying several hours in a car house, or small shop. Ordinarily the car is jacked up and, if a double-truck car, the truck is run out and the work done from above with the aid

of a chain hoist or a crane. Figs. 179 and 180 are sketches of the apparatus for handling wheels employed on one road, and

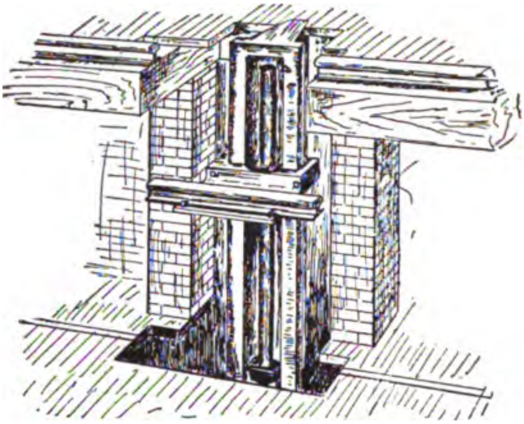


Fig. 179.—Wheel Elevator.

substantially the same arrangements, with slight modifications, are in use on a large number of roads. Fig. 179 shows one side

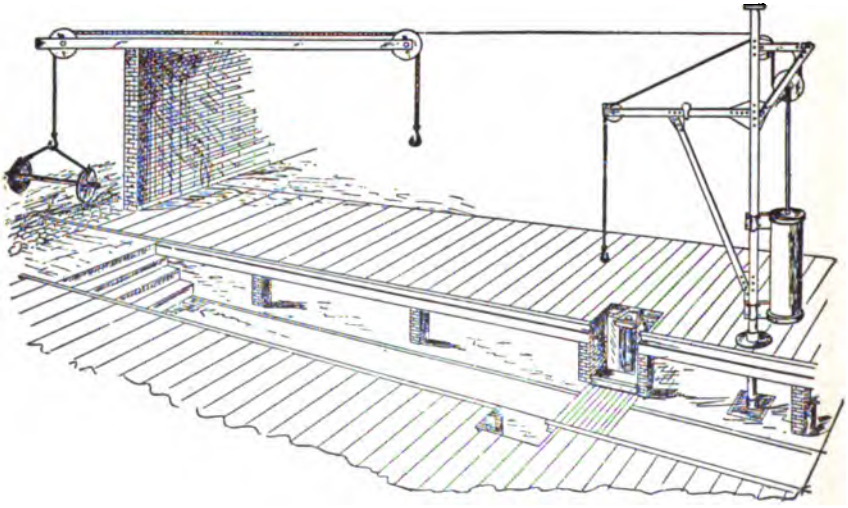


Fig. 180.—Wheel Handling Apparatus.

of a wheel elevator. A short section of the track is attached to a casting through which passes a vertical screw. The casting acts as a nut on this screw and moves up and down, guided

by the upright posts shown. An electric motor in the pit drives both screws, through a connecting shaft with bevel gears on each end.

The pair of wheels to be removed are run on the short section of rail, and after truck and motors are blocked the wheels are lowered into the pit, where they are received by a small truck or transfer table and removed to one side. The new pair of wheels are similarly brought up and raised into place in the truck. This whole operation has been performed and the car ready for service in forty minutes.

Fig. 180 shows other methods of lifting and transporting wheels from the pit with the aid of a compressed-air hoist.

Armature stands or holders for winding armatures are usu-

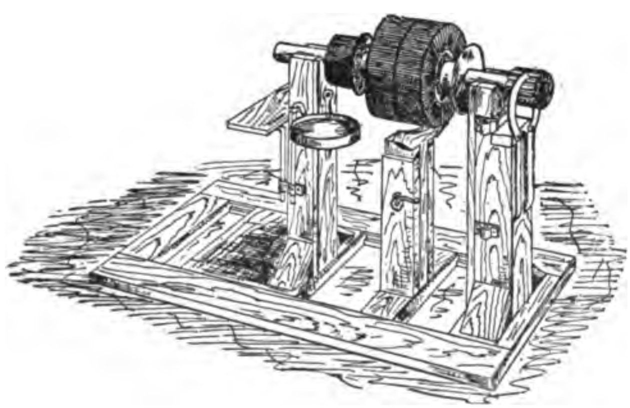


FIG. 181.—Armature Stand.

ally the ordinary X horse in which the ends of the shaft are held in the crotches, with the addition of a tray or shelf for tools. Fig. 181 shows a stand designed by one road, which is a considerable improvement over others in use.

One support is adjustable to suit different lengths of shafts. A center support is provided which is adjustable vertically, and serves to take the weight of the armature when the commutator is removed or applied. A pair of hooks can engage the pinion when the commutator has to be turned or twisted on the shaft.

When a car is completely disabled so that it cannot be hauled in, due to an accident to the trucks, as a broken wheel or axle, it is sometimes difficult to decide on what is the quickest

way to do it, especially when proper wrecking tools, or an extra truck, are not close at hand. Fig. 182 shows a wrecking plank used by one road for this purpose. A is an oak plank 3 inches by 14 inches by 7 feet 3 inches. Two pieces of old steel tires, C, properly recessed on the inside to fit the plank, are bolted to it as shown. The top blocks, B, vary in thickness, depending on the height of the truck frame above the rail.

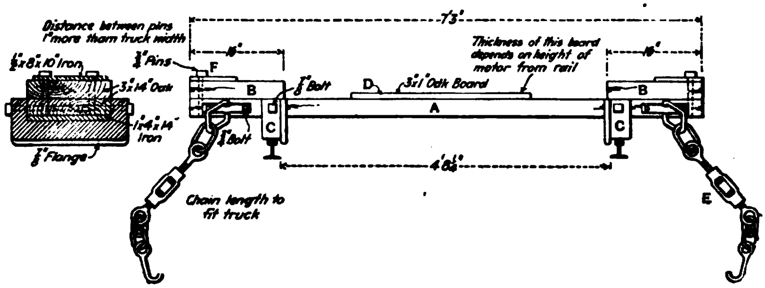


Fig. 182.—Wrecking Plank.

The board D, which carries the motor, if on a broken axle, also varies in thickness. The plank A should be sheathed with sheet iron on the under side, as it is but 2⅝ inches above the rail, and may strike crossings in some localities. With a good motor car for towing, this wrecking plant, with a pair of jacks, will make short work of a disabled car, the good motors of which may be used to help move it.

CHAPTER XIV

MAINTENANCE OF EQUIPMENT

Repairs

For the successful and economical maintenance of the cars of any railroad system there are three fundamental conditions necessary:

First: Proper facilities for doing the work.

Second: A systematic organization.

Third: The careful education of the men handling the equipment in service and the earnest co-operation of the entire operating department.

There will be a difference of opinion among mechanical men as to just what are proper facilities, when they are limited by the amount of the appropriation for their purchase. Generally speaking all will agree that there cannot be too many tools and special labor-saving devices furnished, providing said devices can be kept reasonably busy.

The motive-power department of a steam road was once requested by a shop foreman to purchase an additional lathe for turning driving wheel tires, an expensive piece of machinery. He was at once requested to submit an estimate, derived from previous records of work, of how many hours per day this lathe would be idle, if any. This principle shows that the purchase of special devices should be carefully considered in the light of the probable amount of use they would get as affecting the cost of their particular class of work. Certain classes of tools are always necessary, but the purchase of others depends on the size of the road, and in consequence the amount of work to be done, as against the cost of having this work done outside. Usually the latter question is of more importance to small roads than to those of average size or larger.

A road of average size may have two or three operating car houses and a main repair shop which may be close to one of these. A tendency has been noticed of late years toward the

practice of doing as little repair work as possible in the car houses, and sending a car to the repair shop on the slightest pretext, often to have work done which requires only about two or three hours, and the labor of perhaps two men. The theory supporting this method is, that it is better to have all mechanics, and repair facilities, in one spot, then lower priced labor may be used in the car houses; the work done in the latter being merely sweeping, cleaning, oiling, inspecting and renewing brushes and trolley wheels. In short, the doing of any work in the car houses which requires machine tools is discouraged. The result usually is, that the repair shop is often overcrowded with cars requiring short repairs, such as the renewal of field coils or armatures, and seriously retarding the work of general repairs, which must go on steadily the year round. It also frequently results in a car house being temporarily short of cars to supply the service assigned to that house. More recently opinions are changing regarding the system of repair work, and methods followed by steam roads in the repairs to rolling stock are advocated.

Their methods are well known. The so-called minor repairs, or running repairs, are done by a force of mechanics in the various round houses, and on the "rip tracks" in railroad yards. Then, at stated intervals, or when considered necessary by the division master mechanic, the locomotives and cars are sent to the "back shop," or main repair shop, where they receive general repairs, which is a thorough overhauling. This method, in which the minor light repairs necessary to keep a car in service are done at the car houses, is the best for the average electric road. There may be, of course, a difference of opinion as to where to draw the line between minor and general repairs, and there are some repair jobs where it will be necessary to send a car to the main repair shop which does not require a general overhauling.

The various classes of work done at car houses should include the following: Inspection and cleaning of electric equipment; adjustment and overhauling of brakes; renewal of wheels and truck parts; minor repairs to car bodies, such as replacement of broken windows and car fittings; minor repairs to electrical equipment, such as the renewal of motor bearings and brushes, and the substitution of new armatures and field coils

for those damaged; the renewal of gears, pinions, controller parts, trolley bases, poles and wheels and repairs to car wiring. This does not include such work as rewinding armatures and fields, pressing wheels on or off axles, grinding or turning wheel tires, or work of that character. Such work as must be done on a car which has been in collision or derailed is general repair work and should be confined to the main shop.

While it is true that all repair work must be charged to maintenance, it is sometimes the custom to keep the accounts of car-house repair work separate from those of the main shop, and this is a good plan, for it gives an opportunity to get at the cost of running repairs of each individual car, and in comparing these costs with mileage, and other records of the car, an idea can be formed of the performance of different classes of equipment—information which is most valuable. It may not be advisable to go too heavily into clerk hire, but as each car house should have a storekeeper who gets all his supplies from the main shop, he should be able in most cases to keep records of costs, if not of mileage, for the latter is generally attended to in the main office.

The by far most important work in a car house, which affects the cost of maintenance, is inspection. The theory of rigid inspection is to discover all faults in the mechanism of a car which are developing, before they have appeared as a breakdown, and correct them at once. In other words, it is looking for trouble where perhaps it does not exist at the time, but is always imminent. Some people say, why worry over the breaking down of this or that piece of apparatus, before it has happened? Why not wait calmly for it to break and then repair it? That is not good practice, for it always costs less to prevent an accident to a machine than it does to repair it. Extreme vigilance always results in a low cost of maintenance. Necessarily nearly all car-house inspection work must be done during a few hours at night, when the cars are in the house. At the same time they must be swept and windows cleaned. It has been claimed that night work, as regards inspection, does not attract good and efficient men. The only answer to that is: Make it attractive by increasing the pay, for it is cheaper in the end. The work does not consist of inspection only, but of also making many light repairs, such as setting up

loose nuts, renewing lost bolts, worn-out controller fingers, trolley wheels, motor brushes and oiling bearings. But all work which requires so much time that the required number of cars could not be inspected, should be reported to the day force for their attention; as most of the work must be done by day, holding in the house such cars as require it. A good plan is to have each inspector, or pair of inspectors, as the case may be, turn in a report to their foreman giving the work done on each car, with its number. Then if the car comes "back on them," as they say, it can generally be found whether the break was due to their negligence or that it could not well be foreseen. This has the effect of making men more careful, and thus increases the efficiency of the organization. In any event the work should not be done in a haphazard way, but systematically, and the aid of the operating department can be made of great value.

The car crew should be carefully instructed in the purpose and operation of each piece of mechanism under their charge. The information should be given through an instructor, or a book of questions and answers, or both, as is the practice on steam roads. Examinations might be held periodically, and they should arouse the interest of the men, and at the same time give an idea of their individual efficiency. About the best plan is to require them, more especially the motormen, to serve a few weeks in the car houses, on both day and night work. This gives the men knowledge of what usually happens to a car, and what is done to repair it. They are then able, in most cases, to give an intelligent report of accidents to their car. Unfortunately this training of the men in the car houses is not always possible for several reasons; some roads think they should work without pay; but generally the demand for good motormen is in excess of the supply, and there is not time to put them through this training. A man who has received some instruction usually becomes interested in the mechanism, handles his car carefully, knows whether the car is running properly by the "feel," and frequently does a little inspecting on his own hook during "lay overs" at the ends of his run. All motormen should be provided with a set of blanks, on which is a printed list of the usual troubles. When anything is wrong with the car which needs attention, he

marks the blank opposite the name of the trouble, and signs his name, with the car number, and time of giving up the car. If there is no trouble that he is aware of, he marks it O. K. and signs as before. If the inspectors find trouble on a car marked O. K. which the motorman should have noticed, it is reported, and he is questioned about it. If the men of the mechanical and operating departments are in perfect accord such a system works greatly to the benefit of the company.

On some large interurban systems the education of the motorman in the making of light road repairs is insisted upon, and each is provided with a small box containing a few necessary tools and supplies, such as a hammer, a wrench, a pair of cutting pliers, a roll of tape, an extra trolley wheel, and a few carbon motor brushes. This tool box is frequently made a part of the equipment of the car and the men have keys for it. In some cases the box is issued to each motorman, who takes it with him when he is relieved, and is held responsible for it. The men are also supplied with copies of a drawing showing the plan of the car wiring in its simplest form, and they are especially instructed on the controller and motor connections, and the use of the cut-out switches, so that in case of trouble they can readily find which motor is causing it. In this connection it is important to mark, in some convenient place, as inside the vestibule or dash, near the controller, the end number corresponding to the connections; that is, which is No. 1 end and No. 2 end. It is astonishing how many small troubles which occur on the road can be effectually remedied. The reconnection of a motor lead, the taping up of a spot where insulation has chafed through and grounded a lead, the reattachment of a ground wire, or the adjustment of some controller fingers, are among those troubles which seriously interrupt the operation of the car, and yet are exceedingly simple to repair. Fortunately as time goes on, improvements in car wiring are steadily being made, and the number of these small accidents to the equipment is rapidly growing less. In city service, the practice of educating the motorman in the details of repair work has sometimes been found to obstruct traffic, on account of the motorman's attempts to make repairs on the road when the car should be hauled in. The education of the

motorman in running the car is of equal, if not greater importance, than his ability to make light repairs. It is a fact that the manner in which a car is handled has a marked bearing on the cost of maintenance. A man, either through ignorance, or carelessness, may cause trouble to develop on a car very easily. Throwing on the controller too rapidly, running on resistance points, trying to start without releasing the brake, unnecessarily or improperly reversing, or failing to cut out a defective motor, are examples of what the badly educated motorman may do. Cases are not infrequent where a man has the same car nearly every day, who always turns in the car in good condition, and yet his relief frequently has trouble with the same car, and lack of instruction is evident by the word "grounded" being used in his report as covering all electrical troubles. There will always be a difference in men in any business. If the inspectors of the operating department will notice, and report to the superintendent any improper handling, or carelessness, an improvement in service and a reduction in cost of maintenance will result. But where the inspectors are careless or not sufficiently intelligent, bad practices are developed until the economical operation of the road is seriously affected.

A general foreman of wide experience in maintenance of rolling stock has said: "One of the most important factors we have to deal with in this problem is the education of electrical inspectors and repair men. I am of the opinion that sufficient attention has not been given to obtaining, instructing and retaining in the service competent men, and when we consider that about two-thirds of the cost of maintenance is chargeable to labor account, it certainly seems that too much attention cannot be given this point. Greater inducements should be offered to attract capable and reliable men to the service. It is not merely a question of wages—congenial surroundings are necessary. Car houses should be properly laid out for the work, kept clean, well lighted and heated in cold weather." The above is sound common sense, for proper attention given to the welfare of the men pays in the end. The same authority speaks of the education of these men: "Men should be taught why—as well as how—to do work, and to work from cause and effect. They should read

the effects to find causes, and not guess at them." The man who "knows it all" is of little use, for he cannot, or will not, learn any more. Another question that arises is, Do we give the brains we employ on the car-maintenance problem sufficient insight into the general methods of economical maintenance which have been developed on other systems? It must be borne in mind that the most successful men in car maintenance are those who have grown up with the work, and do not necessarily receive their ideas from what they read, but gain their information from what they see in practical work. It is undoubtedly true where the management allow their foremen to visit other repair shops, good, bad or indifferent, that they pick up certain methods in the handling or repair of the equipment, which could be economically introduced in their own shops. A man who is, year in and year out, kept right down to his own proposition, gets into a rut. It is not the fault of the man, it is human nature, and he continues to apply old methods to new conditions at a loss to his employers. This man could be broadened in his ideas, and made a more valuable employee, by the co-operation of his employers in allowing him to gain a broader view of the maintenance problem.

We must remember that the maintenance shops in the country are isolated factories producing the lowest car-mile cost for maintenance within the experience, or ability, of their operators, due to the independent methods by which maintenance is being carried on. The men on whom we rely for the performance of these duties have been too long in the same shop, and they may have become discouraged or indifferent. When this condition exists the maintenance conditions are changed, and instead of hustling to-day and using such inspection methods as will show them the physical condition of the equipment and how to maintain it, they are waiting to repair the equipment to-morrow, and they consider their salary earned if there are sufficient cars to operate and maintain the schedules.

These are not ethical principles of street-car maintenance, but are conditions actually found where high-maintenance costs exist. Where broader methods are used with the employees we find, not only lower maintenance cost, but greater life is obtained from the equipment. This is the outcome of the ex-

perience of a large number of repair shops throughout the country, and it reflects in the cost per car-mile, and in the possible earning capacity of a railway property.

There is also a policy of management which affects these costs in some cases. Where a spirit of rivalry can be engendered between different repair shops of the same system on the basis of maintenance cost, it has led to a greater economy. It has been found that between the operating and maintenance departments of some systems there is insufficient harmony in their relations. There is a tendency to relieve the responsibility of one department by throwing the burden on the other, not realizing the fact that it is the duty of both departments to produce the greatest number of car miles possible at the lowest cost. From this condition has arisen a movement to put the operating and maintenance departments under one head, and this officer to be responsible in turn to the general manager for both the use and abuse of the equipment.

Such an organization could maintain the present standard of practice and remove the friction that now exists between these two departments, in some systems.

It is possible on some roads to inspect nearly all the cars every night. The frequency of inspection depends on local conditions and the equipment. It can be easily found by experience on a particular road, how long a certain piece of apparatus can be relied on to work without interruption, and in that way the question of how often it needs inspection may be determined. Records should be kept, whether inspection is on a time or mileage basis, in order to be systematic.

On one large system the inspection is divided as follows:

Trolleys: To see that the pole is straight and secure in the stand; that the harp is tight on the pole and that there is sufficient wear in the wheel to last until the next inspection; that contact springs, washers, bushings and axle pins are in good condition and properly lubricated.

Controllers: To see that they are clean and properly lubricated; that contacts make and break at the proper points; that fingers and tips are good for a few days' wear, and that they are not rough and cutting; that cut-out switches work properly, and that wires are firm, and make good contact in terminals.

Main Switches, Fuse Boxes and Lightning Arresters: To see that contacts are clean and in good condition, and that wires are secure in terminals.

Resistances: To see that they are held in place securely; that they are not seriously burned, or grids cracked, and that connections are firm.

Motors: To see that connections and leads are secure and not chafing; that brushes are not broken, and are good for several days' wear; that the brush holder insulation and yoke are clean, and sufficient tension in springs; that commutators are in good condition, and motor bearings properly lubricated; that clearance between armatures and pole pieces is sufficient; that pinions and gears are tight; that gear case and axle-box bolts are tight, and gear cases not cracked.

Loose gears, or pinions, can be readily detected by the motorman, and the interval after which it is necessary to open the gear case to examine pinions and tighten gear bolts, must be determined by experience. At longer intervals motors should be opened up for inspection and cleaning, and especially should a close watch be kept on the armature clearance, either by noting the wear on the bearing linings or, where possible, by measuring the clearance directly by inserting taper steel wedges between the armature and the lower pole piece. These wedges taper from about $\frac{1}{32}$ inch to $\frac{3}{16}$ inch, and are about 1 foot long. Trolley stands should also be cleaned and lubricated, and poles tested for tension. Controllers should be taken apart once a year, and cleaned, and painted, and reinsulated.

A suitable repair and inspection force for a car house of average size should consist of a day and a night foreman; the day force to include a carpenter, a blacksmith and his helper, and two motor and truck repairers, or pit men, with a helper each, a total of seven men and a foreman. The night force depends entirely on the number of cars to be gone over each night, and may consist of two electrical and mechanical inspectors, and three cleaners and oilers; a total of five men and a foreman.

The number and arrangement of these forces on one large system is shown in Fig. 183.

This road is a large one, as seen by the number of car houses, and the particular attention given to night inspection. In only

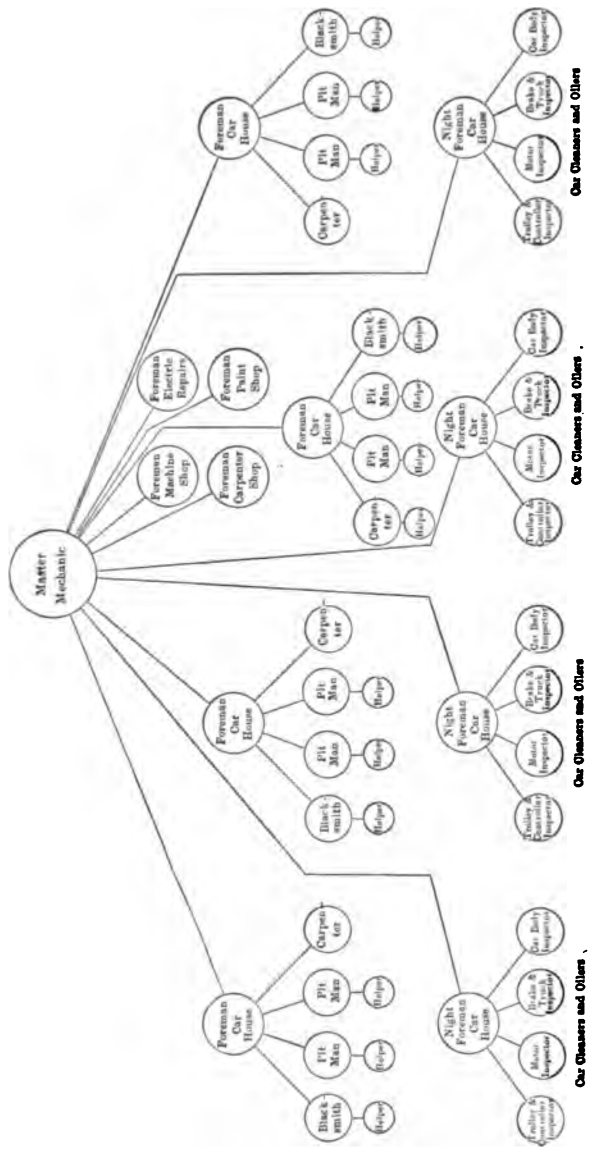


FIG. 188.—Arrangement of Operating Forces in a Large Railway System.

a few cases, as on roads which are wholly interurban, is it possible or practical to do away with night inspection and do such work by day, unless there are sufficient surplus cars.

All work done on the cars in the car houses should, of course, be noted on blank report forms by the day and night foreman, and forwarded to the master mechanic. He, in turn

Form T. 5M-6-15-'01.

UNITED TRACTION COMPANY ....CAR HOUSE

Daily Report of Foreman to Master Mechanic

..............................190

No. Repair Men on duty—day,

No. Repair Men on duty—night,

Total Cars on hand at 6 p.m., No. Cars O.K. not in service.

CARS IN BAD ORDER AT 6 P.M.

Car No.	Trouble.	Car No.	Trouble.

CARS PULLED IN SINCE LAST REPORT.

Car No.	Trouble.	Car No.	Trouble.

Remarks:

should have these reports tabulated in such a form as to show at a glance whether certain troubles were increasing from year to year, or not. It would also show

a very good record of the behavior of the various apparatus, which is valuable information.

One form of such daily report is shown on page 329, also a record of the life of different car-equipment parts on a mileage basis from one road is given below.

TABLE XXVIII

LIFE OF DIFFERENT CAR-EQUIPMENT PARTS

Part.	Type of Motors (all Westinghouse).	Type of Car.	Average Mileage.	Remarks.
Carbon brushes..	Four-49	St. Louis 28 in. body Stephenson 26½' body	14,909	Double truck cars
" ..	Two-38b	St. Louis 28' body	10,866	" "
" ..	Two-49	Brill 21' body	13,117	Single "
" ..	Two No. 3	" 18' "	11,846	" "
Arm. Bearings ..	Four-49	Stephenson	8,480	Double "
" ..	Two-38b	St Louis	7,812	" "
" ..	Two-49	Brill	9,582	Single "
" ..	Two No. 3	"	10,297	" "
Brake-shoes	....	St. Louis & Stephenson	17,726	Double "
"	....	Brill	11,648	Single "
Car wheel.......	....	St. Louis & Stephenson	23,668	Double "
"	....	Brill	19,963	Single "
Gears	....	Stephenson	96,238	Double "
Gears	....	St. Louis	84,912	Single "
Pinions	.. ..	Brill	20,988	Double "
"	....	"	24,636	Single "

CAR WHEELS

The subject of wheels is one to which every railway manager should give the most careful consideration. Up to perhaps four years ago about the only wheel used under an electric-motor car was the ordinary cast-iron wheel with the chilled rim, a development of the old horse-car wheel. Thousands of chilled cast wheels, greatly increased in strength, and weighing from 450 to 700 pounds each, can be found under standard freight cars. Other wheels are now coming into use, such as the steel-tired wheel with cast-steel or cast-iron center, which is the same as used by steam roads in its construction; the fused-steel tired wheel, Figs. 184, 185, 186, consisting of a forged-steel tire within which is cast the center of cast iron, so that the latter practically fuses into the tire; and the rolled steel wheel, which

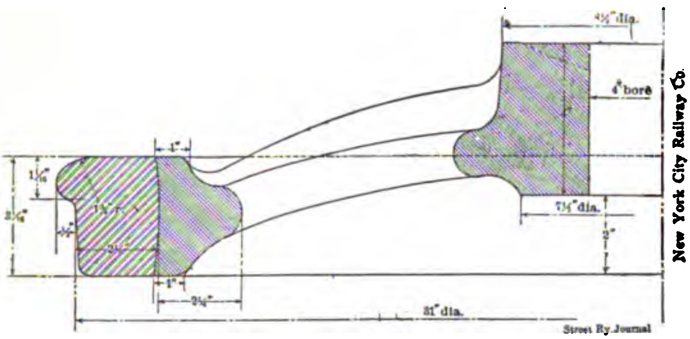


FIG. 186.—Fused-Steel Wheel Used on New York Surface Lines.

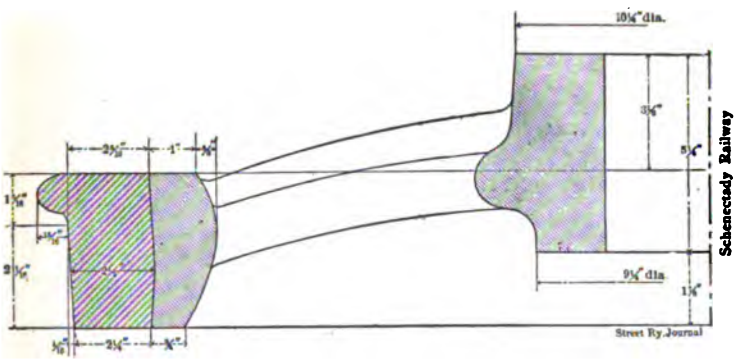


FIG. 185.—Fused-Steel Wheel Used in Schenectady.

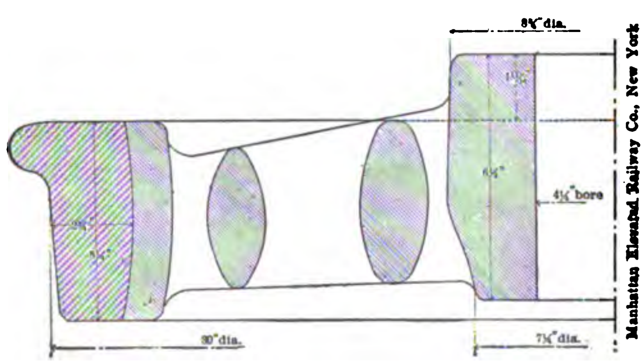


FIG. 184.—Fused-Steel Tired Wheel-Used on New York Elevated Lines

has a plate center, and made of cast steel rolled while hot into the desired shape by passing it through the necessary rolls.

The railway company is chiefly concerned with two questions: safety of the passengers, and the cost of wheels, in other words, the cost per 1,000 wheel miles. When both the weight and speed of electric-motor cars began to increase, and especially on interurban lines, the small flanges of the chilled cast-iron wheels began to show an increase in the amount of chipping and breaking which became dangerous, causing a number of derailments. Probably most of these flange breaks occur while the interurban car is passing over the grooved rail and special work in the cities, and the danger arising from a broken flange occurs after the car has resumed high speed. The increased speed has rendered it necessary to slightly increase the depth and thickness of the flange for safety, and this has made the conditions in the cities worse. Some interurban roads are running at high speed to-day, wheels with a tread $2\frac{1}{4}$ or $2\frac{1}{2}$ inches wide and a flange $\frac{3}{4}$ inch deep. There may be those who are willing to maintain that the above is a safe practice, but the majority of railway men used to high speeds will declare it entirely unsafe. Such wheels, set at standard gauge, or 4 feet $8\frac{1}{4}$ inches from gauge line to gauge line, will not pass through the frogs of a standard gauge steam road without frequently dropping off, and no steam road will haul a car so equipped over their lines even at freight-train speed. A few high-speed interurban roads are fortunate enough to be able to use wheels with the M. C. B. standard tread 4 inches wide, and flange $1\frac{1}{8}$ inch deep, but the cars of these roads seldom run over the ordinary street-car track.

A majority of the roads have now adopted a compromise wheel, with a flange $\frac{7}{8}$ to 1 inch deep, and a tread 3 inches wide. This is reasonably safe, but suffers when made of chilled cast iron and run in cities. Where special work is worn down the car rides on the flanges, this chips and breaks out sections of the flange, and the outside of the tread projecting over the rail-head frequently rides on paving blocks which are higher than the top of the rail. Steel tires overcome much of this difficulty, as they do not break, and in consequence are far safer. Even such wheels whose flanges are too deep for the grooved rail wear badly, and cause more power to be consumed

by the car. It seems as if no relief can be expected from these troubles until some concessions are made by cities which insist upon a grooved or tram rail in a paved street.

As regards cost of wheels, a large amount of data concerning chilled cast wheels has been published, and under average conditions the results agree that the cost per 1,000 wheel miles is from 18 to 22 cents, and the life of a wheel from 30,000 to 40,000 miles. Some manufacturers sell cast-iron wheels under a guarantee of a life of 40,000 miles, and some sell such wheels on a mileage basis. In this latter plan a price is agreed on per 1,000 wheel miles. The car mileage of the different classes of cars is given the manufacturer who keeps the road supplied with wheels, and his price may, or may not, include regrinding for wear and flat spots. It is a very satisfactory arrangement for both sides, as each is interested in obtaining the longest possible life of each wheel.

Comparatively little data are available on the life and cost of steel tires, or of steel wheels, because they have not been in use long enough, and it is said that no all-steel wheels have yet been worn out. The life of steel-tired wheels on steam roads can hardly be used as a comparison, for the reason that all their cars are hauled, and the tires are not subjected to the increased wear caused by the motors spinning the wheels. Steel-tired wheels will seldom develop flat spots from sliding, and if they do they have the faculty of rolling them out after a short time. It has been said that if a road adopts steel-tired wheels, there will be no saving of cost over cast wheels, if the steel tires have to be sent away when they require turning down. All roads using such wheels should be equipped with a tire-turning lathe of their own. The saving made will soon pay for the cost of the lathe. Fig. 187 gives a section of steel tire.

The following data were given by one large railway system on city and suburban service.

The cost of cast-iron wheels had been about 20 cents per 1,000 wheel miles; wheels cost from $5.00 to $7.00 each. A new steel tire costs $12.00, and with the three turnings after each 50,000 miles of service will make the net cost $3.00 per 50,000 miles, or 6 cents per 1,000 miles; adding to this a shop cost of $1.00 per wheel for the original application of the new tire to the center, which also applies to each truing-up opera-

tion in the lathe, the gross cost per 50,000 miles is brought up to \$4.00. Even this only increases the gross cost per 1,000 miles to 8 cents, which is considerably less than half the cost of the cast-iron wheel. The idea that the steel-tired wheel is the more expensive to use on account of its high first cost, *i. e.,* \$30.00 to \$40.00 each, is misleading, because the center of this wheel never has to be renewed, and should be considered as a part of the truck. It seems perfectly fair to make the above assumption when comparing costs, as the only renewable fea-

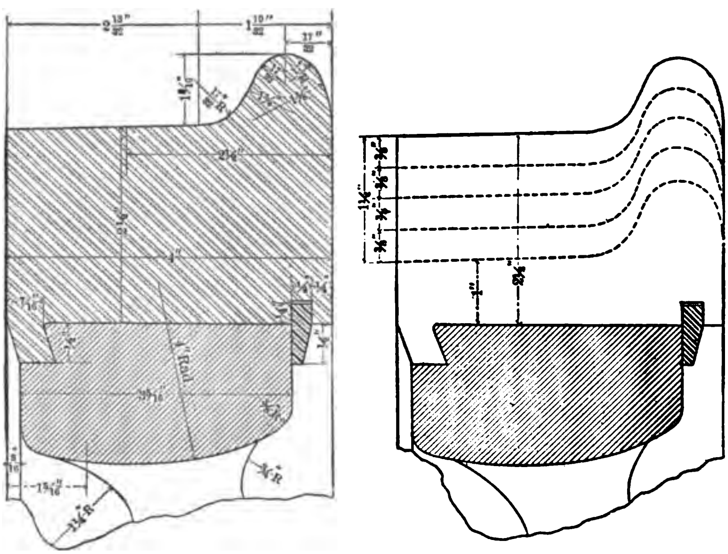


Fig. 187.—Section of Steel Tire Showing Dimensions when Trued up in a Lathe at Different Periods During Its Life.

ture of the wheel is the tire. The only additional cost to be considered is that of removing a worn tire and replacing it by a new one, besides the necessary turning in a lathe about every 50,000 miles, and this has been allowed for in the above cost. As a matter of fact the removal and replacing of cast wheels as well as the regrinding necessary to equal the life of a steel tire may more than offset this cost.

The life of a steel tire, of course, depends on the thickness of the tire, and the permissible reduction in wheel diameter depends on the clearance over the roadbed. Wheel sizes are or-

dinarily designated as 30, 33 or 36 inches in diameter, but are usually from 1 to 1½ inches larger when tires are new. Cast wheels can seldom lose more than 1 inch of diameter, on account of the depth of the chill, which is usually about ⅝ or ¾ inches. Steel tires are generally made from 2 to 2½ inches thick, allowing a reduction of wheel diameter of about 3 inches,

FIG. 188.—Rolled-Steel Wheel.

and this is believed to correspond to a life of approximately 200,000 wheel miles under average conditions.

The rolled steel wheel is capable of still further wear. While its tire can be practically any thickness desired, the wear is only limited by the maximum reduction of wheel diameter, and the wheel can be worn down until it is unsafe for further use. There are no data available as to the comparative cost of rolled-steel wheels. Figs. 188 and 189 show rolled-steel wheels.

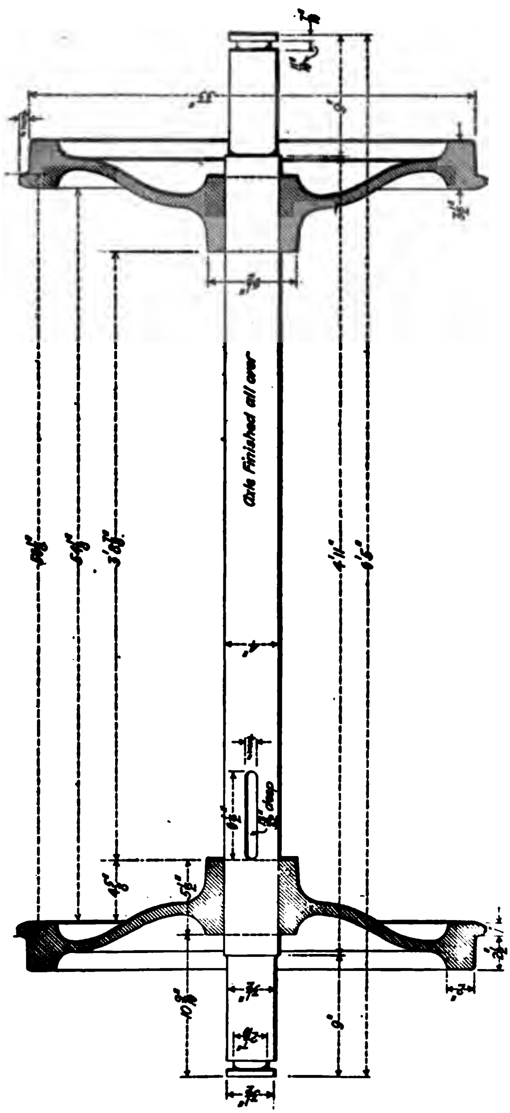
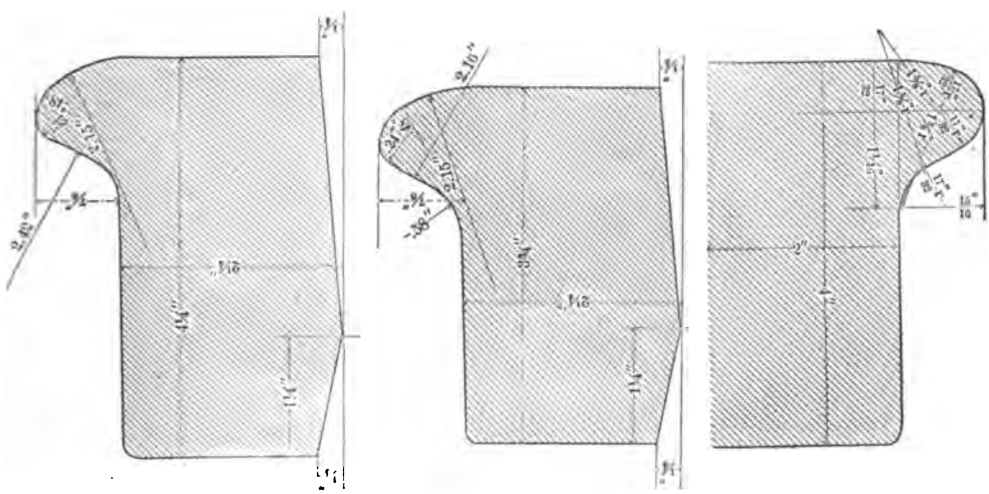


FIG. 189.—Rolled-Steel Wheels Mounted on Axle.

Another reason besides that of reduced cost has influenced railway companies to adopt steel wheels, and that is the necessity for frequently taking cars out of service for renewing or regrinding, as is the case when cast wheels are used. The car service lost from that cause in a year amounts to a very considerable figure.

An important point in purchasing steel tires is to decide upon the character of the service in which they are to be used. Manufacturers of tires supply thousands to all classes of steam



FIGS. 190, 191 and 192.—Dimensions of Steel Tires Used on Interurban Roads.

locomotives, and the grade of the steel in a tire to be used on a freight locomotive is quite different from that on a fast passenger engine. There should be possibly as much difference in the tires used on high-speed interurban cars and those on cars in city service. Attention to this point will give a noticeable increase in the mileage obtained from tires. Fig. 187 shows a section of a typical interurban tire with dimensions and indicates the dimensions when trued up in a lathe each time. In pressing steel-tired wheels on axles, a difference in diameter between the bore of the hub and the seat of the axle of .01 inch is recommended. Opinions differ somewhat as to the amount of pressure used, but in general about 10 tons per inch of

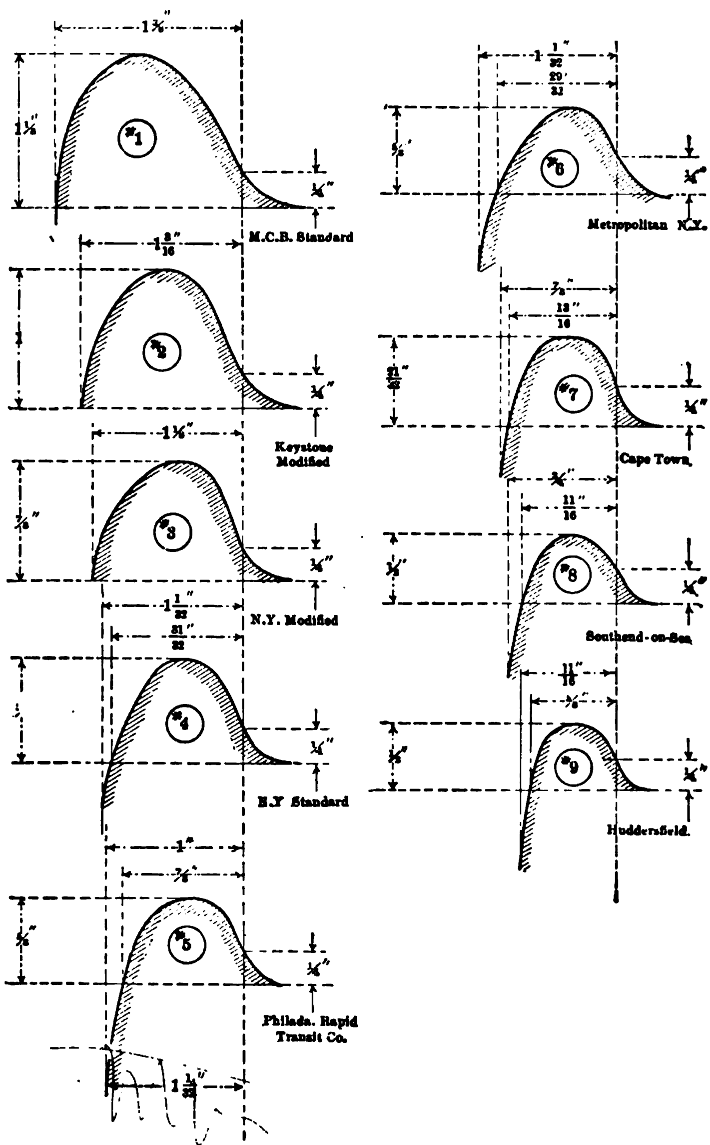


FIG. 193.—Standard Flanges Adopted by J. G. Brill Company.

axle diameter is sufficient. Figs. 190, 191 and 192 show various dimensions of tires in use on interurban roads.

The question of the proper design and dimensions of car wheels and axles often comes up on a road when the management are considering the purchase of new equipment. It is proposed to give here a table of the dimensions of the different wheels in common use which is expected to be of value as a guide to the selection. The chemical composition of a cast-iron wheel is usually left to the manufacturer, to whose interest it is to provide the best. A recommended composition is as follows:

	Per Cent.
Total carbon	3.50
Graphite carbon	2.90
Combined carbon	0.60
Silicon	0.70
Manganese	0.40
Phosphorus	0.50
Sulphur	0.08

Successful wheels, however, varying in some of the constituents to a considerable extent, have been made. Regarding one of the most important points in the design of wheels, that of the dimensions of the flange, average practice may be seen in Fig. 193, showing the standard flanges adopted by the J. G. Brill Co. A large number of cast-iron wheels made by a leading manufacturer have the following principal dimensions:

Diameter.	Tread.	Flange.	Weight.
30 ins.	3 ins.	$\frac{5}{8}$ ins.	275 lbs.
30	3	$\frac{5}{8}$	360
30	$2\frac{1}{8}$	$\frac{3}{4}$	270
33	3	$\frac{7}{8}$	510
33	$2\frac{1}{2}$	$\frac{5}{8}$	400
33	$2\frac{5}{8}$	$\frac{3}{4}$	450
33	$2\frac{1}{2}$	$\frac{3}{4}$	420
33	3	$\frac{7}{8}$	425

Fig. 194 gives the sketches of the dimensions needed by the manufacturer on receiving an order for wheels.

A. Diameter of wheel.

B. Diameter of front hub.

C. Diameter of back hub.

D. Distance through hub.

E. Projection of front hub beyond rim.

F. Recession of front hub under rim.
G. Projection of back hub beyond flange.
H. Distance over flange and tread.
K. Number of arms or brackets.

The following table gives dimensions of cast-iron wheels which have been made from the above:

Dimensions in inches.

Weight	A	B	C	D	E	F	G	H	K
420	30	7⅛	7⅛	6	⅛		¾	4	7
380	33	7⅛	7⅛	4⅛		2⅛	3¾	3¼	7
400	33	8¼	8¼	4⅞		2¼	3¾	3⅝	7
400	33	8¼	8¼	4⅝		2⅛	3⅛	3⅝	7
470	33	8¼	8¼	4⅝		2	3⅛	3¼	7
490	33	8¼	8¼			2¼ to 3⅛	2¾ to 4¼	3¼	7

Core in hub as specified.

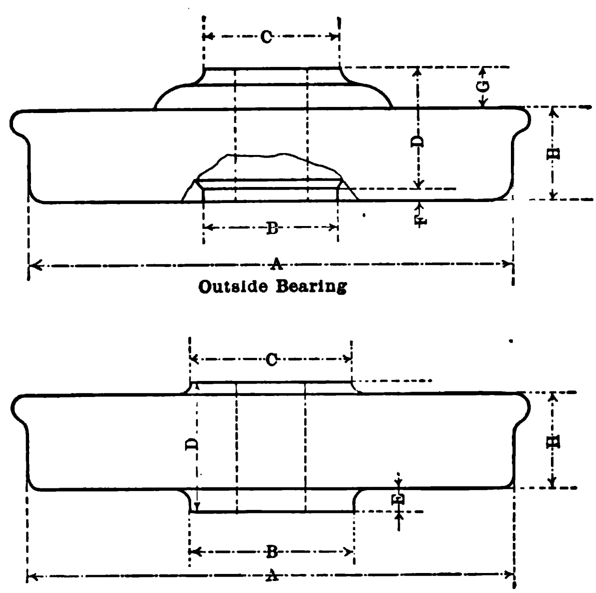
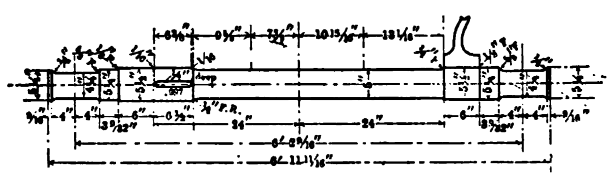


FIG. 194.—Sketch Showing Dimensions Needed by Manufacturer When Filling Order for Wheels.

The necessity for standardizing motor-car axles is becoming more apparent each year. Until comparatively recent times axles have generally been too small. The reason probably was due to a comparison with steam-road car axles being taken as

a sort of basis. This comparison was wrong because steam cars are all trailers, and an entirely different set of conditions exist in their case. It had been found that a tapering iron axle, usually Taylor iron, smaller in the center, was best, because it did not crystallize as readily as steel, and gave a certain flexibility which was of great value. But a motor-car axle is a driving axle, and is to be compared with a locomotive driving axle, rather than one suited for a car. It was, therefore, realized that a heavy steel axle necessarily straight between wheel hubs was the only style to be considered.

Fig. 195 shows an axle the dimensions of which are well suited for average suburban and interurban cars. As an example of standard elevated-road practice as well as heavy high-



STANDARD M. C. B. FILLETS IN ALL OFSETS.

FIG. 195.—Dimensions of Typical Interurban Axle.

speed interurban work the M. C. B. steel-tired wheel and the axle shown in Fig. 196 is given. Of more recent date is the practice of mounting the solid gear on an extension of the hub of one of the wheels, and bolting it to the spokes of the wheels. The use of a solid gear thus mounted has proved to be an improvement over the old split gear keyed to the axle, as it does away with all troubles from loose bolts and worn keyways. In some cases the wheels are pressed on over keys.

Brake Shoes

Every electric railway should, as far as possible, adopt a standard form of brake head, so that all shoes can be of the same design and will fit all cars except where wheel diameters vary too much. This step was taken years ago by the steam roads, and the Christie form of head is used by them all. This head was adopted as standard by the American Street Railway Association in 1901, but the principal incentive to change from existing types to standard, that of interchange of cars, is miss-

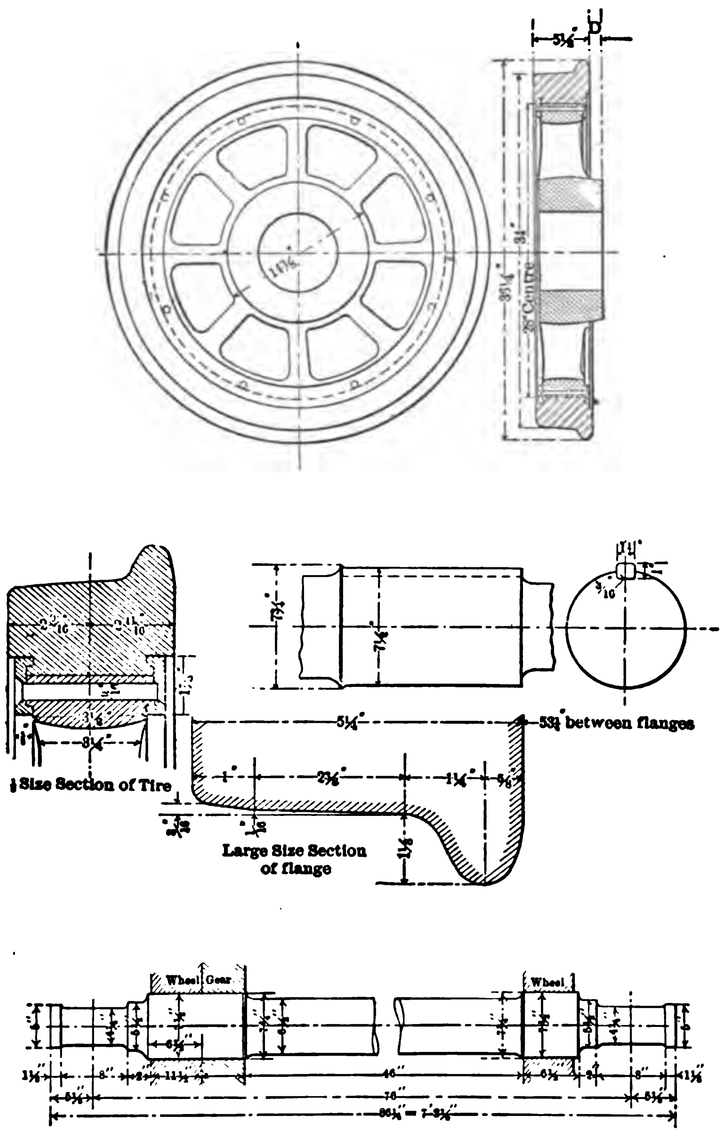


Fig. 196.—Typical Wheel and Axle for Elevated Roads.

ing among electric roads at present, and the process must necessarily be slow. It could be hastened to a considerable extent, however, if taken up by the truck builders and the standard used by them on all new cars, for the design of the brake head is seldom specified except by the largest systems. There is an increasing tendency toward the use of flanged shoes; that is, of shoes made wide enough to fit the wheel flange. With chilled-iron wheels, except under conditions of severe flange wear, it is good practice. With steel or steel-tired wheels they should always be used, for they not only cause an even wear on the wheel flange, but tend to preserve its original contour. In locomotive driver brakes the shoes bear on the flange, and on a portion of the tread nearest the flange, and on the outer portion of the tread, leaving a space untouched where the rail head bears. This wears the wheel evenly and prevents to a large extent the grooving of the center of the tread by the rail. The process is further aided by small pieces of steel inserted in the shoe casting at the portion bearing on the tread, thus turning off the steel tire as in a lathe about as fast as the rail wears the other portion. In consequence the tires do not require truing up as frequently. Figs. 197, 198 and 199 show types of brake shoes for electric-motor cars. The steel or wrought-iron inserts can be readily seen.

The proper composition of brake shoes is a problem which has been studied for many years. Good braking effect combined with lasting qualities is the object sought for. It is generally conceded that soft-cast iron gives the best braking effect obtainable, but with poor lasting qualities, and all attempts to better the latter have been at the expense of the former. Shoes with steel inserts placed parallel to the axle have a cutting effect and increase the wear on the tire while giving fair braking effect. When steel inserts are placed diagonally or lengthwise, the lasting quality is greatly increased but the braking is poor. Soft cast-iron shoes sometimes give trouble for lack of strength, and are made with a steel back plate which effectually overcomes the difficulty. Other shoes are made with alternate soft and hard chilled sections. This shoe is widely used and is a compromise between effective braking and length of life. Another cast-iron shoe has inserts of cork or other soft material, the object being to collect on the soft inserts the particles of

FIGS. 197, 198 and 199.—Types of Brake Shoes for Electric-Motor Cars.

iron ground off the hard portion and thus prevent the sliding or glazing of the shoe when grinding stops. This is the reason why shoes made wholly of chilled cast iron are not used. While they have a long life their braking effect is very poor.

The Master Car Builders' Association has adopted the following specifications for brake shoes.

FOR CHILLED CAST WHEELS

Brake shoes tested on chilled wheels moving at a speed of 40 miles per hour must show a mean coefficient of friction of 22 per cent. acting under a load of 2,808 pounds, a mean coefficient of friction of 20 per cent. under a load of 4,152 pounds, and a mean coefficient of friction of 16 per cent. under a load of 6,850 pounds.

FOR STEEL-TIRED WHEELS

Brake shoes tested on steel-tired wheels moving at a speed of 65 miles per hour must show a mean coefficient of friction of not less than 16 per cent. acting under a load of 2,808 pounds, a mean coefficient of friction of 14 per cent. under a load of 4,152 pounds, and a mean coefficient of friction of 12 per cent. acting under a load of 6,850 pounds.

As the increase in speed and weight of motor cars has caused the adoption of power brakes, so also has it caused a proportionate increase in cost of brake shoes. The greater wear, above that of the former low speed cars with hand brakes, has practically doubled the cost of brake shoes per car mile in the past few years. The cost may be said to range between 50 and 60 cents per 1,000 car miles on a large system using many air-braked cars, while on an interurban road using only air brakes, and running at high speed, the cost has been found to be from 15 to 20 cents per 1,000 miles. This difference in cost is principally due to the greater number of miles run per stop.

Car Lubrication

The lubrication of motor car bearings is rapidly passing through a transition stage, and the railway companies themselves have discovered facts regarding grease and oil as bearing lubricators, which had not before been brought to their attention. The motor manufacturers from the beginning adopted

grease as a lubricant and designed all their apparatus to suit. It may be said for them that they were not in a position to make extended tests to determine the question, but it is evident that too little attention has been paid to it, by both manufacturers and railways, in the past. The truck manufacturers on the other hand adopted almost in the beginning, after horse cars went out, what is practically the steam railroad journal box, in which the axle bearing is lubricated by oil-soaked waste packed in the box beneath it. Fig. 200 shows this type. Although changes and improvements are now being made in this form of journal tending to decrease the cost of oil used, it has given good satisfaction for years on thousands of steam passenger and freight cars, as well as on motor cars.

An ordinary four-motor interurban car has 8 wheel journals, 8 motor axle bearings and 8 armature bearings, a total of 24 revolving bearings to be lubricated. That these bearings present considerable resistance to the movement of the car is well known. How much this resistance can be decreased by good lubrication over poor is a question. One authority estimates it at 20 per cent. and he is not far out. In other words 20 per cent. more power is required to drive the poorly lubricated car in the same schedule, than the other. Under the usual grease lubrication the efficiency is lowest in cold weather, for grease cannot lubricate under those conditions until it has been heated sufficiently to become a liquid. This heat must be produced by friction in the bearing, and the power station must originally supply that heat. On all roads, especially large systems using electric heaters, a very considerable increase in output at the power station is inevitable in cold weather, and it is usually charged to the heaters, but how much ought to be charged to bad lubrication? It may be that, as the railways begin to adopt improved methods, we will obtain some comparative figures on this point. An object lesson may be had if we would notice the facility displayed by a properly lubricated interurban car in "drifting" or "coasting" and then note the performance of the other kind with a similar equipment on, perhaps, a different road. The difference may be surprising.

With most railways grease was just grease, and the cheapest kind was usually purchased, but sometimes a surprise was encountered when an agent remarked that he could supply

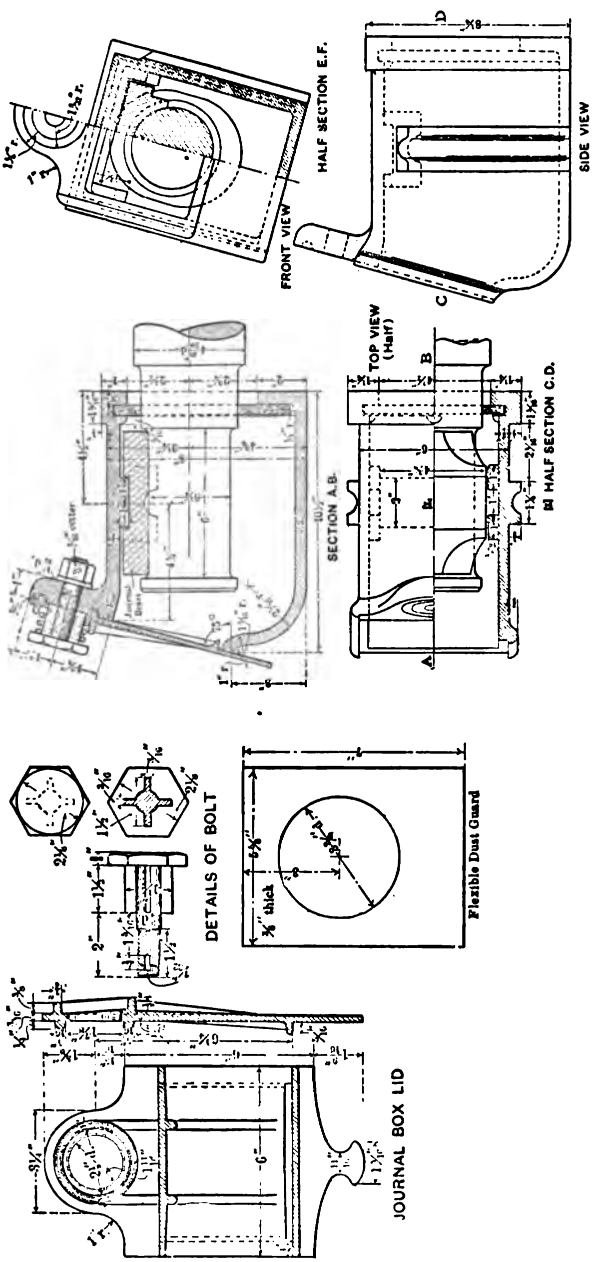


FIG. 200.—Steam Road Type of Journal Box.

grease that contained some real grease; that for equal weight it would lubricate three times the mileage of the old grease; that all bearings would run cooler and that its price was just three times that of the other. He argued better lubrication at less cost, due to the fact that grease cups were only filled once, while the old grease had to be supplied three times. When this was found true, it may have been the beginning of an awakening to the fact that it was possible to improve in lubricants, and that perhaps a substitute could be found for grease which would give better results still.

The probability is that the principal incentive toward better lubrication was the excessive wear of armature bearings. The linings wore down so fast that armatures were continually getting low enough to strike the lower pole pieces, with the frequent result of destroyed bands or burned-out armatures. This, on a large system, was so expensive that a remedy became imperative. A great deal of this trouble was caused by dirt and grit getting mixed with the grease in the cup in many almost unavoidable ways, and not only were bearing linings quickly worn, but the rapidity of the wear on the steel shaft was remarkable. A state of affairs is soon reached when few shafts have the same diameter, and consequently linings of a standard size cannot be carried in stock. Finally the shafts have to be all turned down to a certain size, in spite of the weakness caused, and steel sleeves are heated and shrunk on the shafts. These are then turned to the standard diameter. When it was realized that much of this trouble could be obviated by better lubrication, experiments were at once begun.

It will be remembered that, as far back as 1895 or 1896, it was discovered that very heavy motors, such as were used on third rail lines, could not be successfully operated with grease as a lubricant, and the manufacturers redesigned the bearings so that oil and waste could be substituted. This change was successful and has been retained and improved, but all smaller motors were allowed to be sent out with the grease cups as before. This is causing trouble at present for those roads which have abandoned grease and substituted oil, because the oil has to be fed through the old grease cup. They have designed and tried a number of devices to do this properly, and while some report a considerable saving in cost with very satisfactory

lubrication, others are not yet satisfied with the methods employed. The opinion is becoming universal that oil is a far better lubricant, and troubles caused by the use of grease are rapidly disappearing.

The latest motors for ordinary street and interurban service are now sent out by the manufacturers with all bearings designed for the use of oil with felt or waste. But this does not help the matter of the thousands of older motors which are far from worn out, in which some kind of an oil feeding device must be applied to the grease cups. Several of these have taken the form of a cast-iron cup with a vertical tube in the center, through which a wick composed of woolen strands passes from the oil in the cup. At the bottom of the tube is a small hole leading to the bearing, and the top of this hole sometimes has a small ball or a needle-pointed valve, which is supposed to shut off the oil when the car is at rest, while the jarring of the car when in motion unseats it sufficiently to allow the oil to run. Some say this valve is a failure and omit it entirely. Others regulate the flow of oil by the number of strands in the wick, but the flow is continuous. Nearly all agree that if they could get a device which would positively shut off the oil when still, and start it when the car starts, then oiling would be satisfactory.

It is unnecessary to describe each device which is in use, but Fig. 201 and Fig. 202 show two which are used to some extent.

Fig. 203 shows a form of oil cup used by the Rhode Island Co. of Providence which is said to give satisfactory results. The weight "B" fits easily in the vertical tube "X" and its weight is carried by the spring-supported valve stem "C." The tube "X" has three vertical slots in its sides and the lug "Y" slides in one of them. This keeps the weight and consequently the valve stem "C" from turning as well as the adjusting screw "E." The tension on spring "D" can be adjusted by tension screw "E," thus regulating the quantity of oil admitted through valve "C" by the vibration of the weight, as valve "C" seats upward and the oil is shut off when the car stops. All these cups are designed to fit present grease cups. When wheel journals and other bearings are lubricated with oil and waste as is done by steam roads, it is sometimes the case that considerable trouble is experienced from hot boxes, and those in

charge seem ignorant of the cause. In nearly every case of this kind it is lack of knowledge as to how it is done, and what are

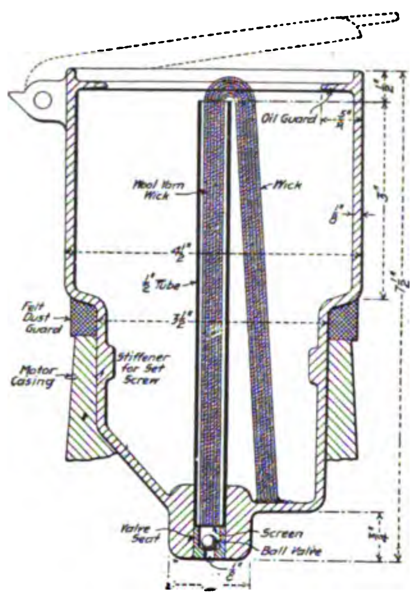


FIG. 201.—Automatic Oil Cup for Motors.

the proper materials to use. It is not an uncommon sight to see a car-house man repack a wheel journal with a quantity of

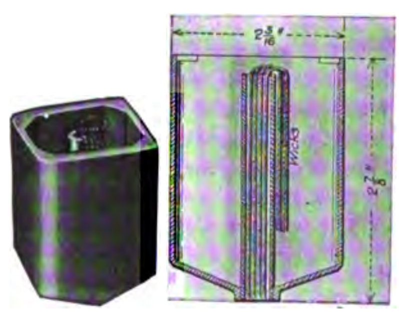


FIG. 202.—Automatic Oil Cup for Motors.

the cheapest colored cotton waste which has been in a pile on the floor, after dipping it in a pail of oil. He forces about all he can into the box with his iron rod, and packs it down

hard; then after pouring about a pint of oil on top of the waste, the job is done. Some roads who use the above method will say: "We don't have much trouble with hot boxes." In such cases a closer investigation will invariably show far too many hot boxes; a high expense for journal brasses, and badly worn axles, the inevitable result of bad lubrication. Often hot boxes occur on applying new journal brasses and the cause is attributed to a rough axle. Far more often are they caused by a few strands of waste being caught under the new brass when put into place. Nothing causes a box to heat as easily as this.

Steam railway men, on sending out a new passenger car, or an old one with new journal brasses, formerly had to send

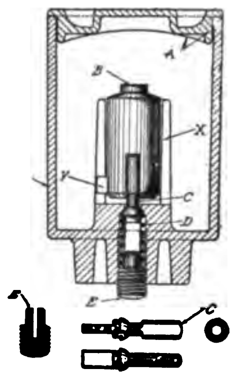


Fig. 203.—Automatic Oil Cup Used by Rhode Island Co.

a man provided with oil, waste, and "dope," on the first trip to look after hot boxes, until things wore to a fit. This is seldom done now, for all new axles, at the bearing fit, are turned to size with the finishing cut of a flat-nosed tool, and then burnished or rolled with a steel roller carried in the tool post of the lathe. The surface is never touched by a file, for that is usually fatal to cool running, but the rolling process smooths off all minute particles and imparts a bright polish to the axle. This, when furnished with a new lead-lined journal brass, is so sure to run cool from the start that the necessity of sending a man with the car has disappeared. For proper lubrication of all bearings designed for oil and waste lubrication, nothing but pure wool waste should ever be used. This should be

soaked in good journal oil for not less than 24 hours before using. Steam roads keep a certain quantity always soaking and use as required. After the box is cleaned the waste should be allowed to drip off what oil it will before it is packed in the box. It should then be spread evenly over the bottom of the box up to a height where it presses against the lower half of the axle. It should not be packed tight but should act like an elastic, springy mass. The wool waste has the required elasticity in a high degree. It is unnecessary to pour in any oil if the waste is well soaked. Lead-lined brasses are universally used by steam roads. They have an inner lining of lead about $\frac{1}{16}$ inch thick. This lining wears off in a day or two allowing the axle and brass to fit themselves gradually, and so prevents the weight being carried by two or more high spots in the brass, which would cause heating.

Some very interesting results have been recently attained, especially by steam roads, with a method of lubrication in

FIG. 204.—Journal Box Showing Method of Lubrication with Rollers.

which the standard journal box is used, but the waste is omitted. In its place several patented devices are being tried, which consist of two or more small wheels or discs supported in various ways which roll on the axle. These wheels are forced against the under side of the axle by a slight spring pressure, and the lower half of their rims being immersed in oil carried in the journal box, their revolutions carry the oil up and deposit it on the axle at the contact points. Care has to be exercised to secure a tight dust guard and other precautions to prevent leakage. (See Fig. 204.) Fig. 205 shows a journal box for electric cars in which a wick is held against the axle, the other end being immersed in oil.

It is just as important to change the consistency of oil in

summer and winter, as it is grease, and some roads change the oil three times during the year. Motor bearings are usually fitted with babbitt metal composition linings, the composition being about as follows: 100 pounds tin, 10 pounds copper, 10 pounds of antimony. The best journal oil is a composition of crude oil, whale oil, and lead, and the cost about 20 cents per gallon. It is a difficult matter to determine at present what the proper cost of lubricating a four-motor car per 1,000 miles ought to be. Some records give from 18 to 28 cents per 1,000

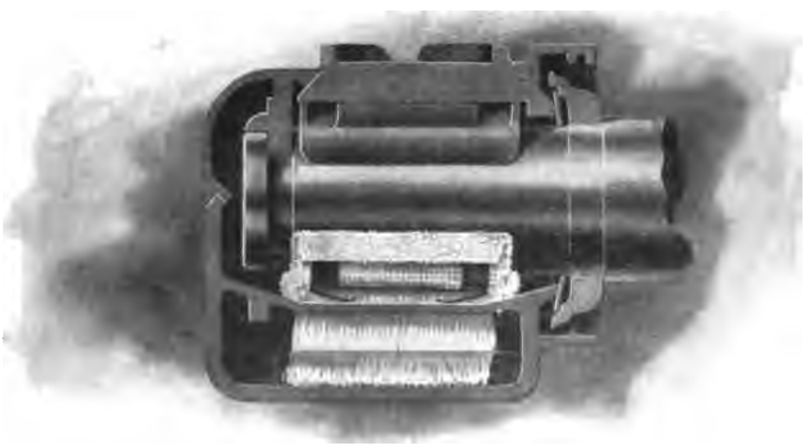


FIG. 205 —Journal Box with Wick Lubrication.

car miles, but with the latest-type motors, built for oil and waste lubrication, it is quite possible to reduce this to about 12 cents. Elevated roads, using two motors per car, have succeeded in getting the cost down to 8 or 9 cents. The Rhode Island Co. claim that their oil cup described above positively shuts off the oil when not in motion, and report that some G. E. 57 motors are running with an average of 2 ounces of oil per bearing per 1,000 miles and that G. E. 800 motors require from 3 to 4 ounces per bearing for the same distance. The oil weighs 116 ounces per gallon. The figures probably refer only to armature bearings.

CHAPTER XV

MISCELLANEOUS SUBJECTS

Freight and Express Traffic

As a general proposition the freight or express business on interurban roads is a widely diversified one. It is vitally influenced by local conditions, especially by competing steam lines. In making the distinction between express and freight the former is usually defined as goods which are collected, transported and delivered, and necessitates in most cases a wagon service at both terminals. The freight may or may not be a heavier class of goods, but is not collected or delivered, simply transported. Thus the distinction is nearly the same as that between the freight carried by steam roads, and that handled by the old express companies.

The road that serves large manufacturing or commercial centers, where prompt delivery and receipt of goods are advantageous to the customer, can generally do an express business, at express rates, upon a profitable basis. On the other hand a road operating through a farming district, can often work up a profitable freight business in milk and farm produce at low rates, even when competing with a steam line.

The advantage which the interurban roads have over the steam roads, in competing for the local freight traffic, is shown in their ability to transport goods frequently, and promptly, between a city and its suburban towns. The frequency of freight service has a decided tendency to build up the small-shipment business, for the merchants in the towns can order their goods one day and receive them the following, or even the same day, which is an advantage to their customers.

Many managers believe that a strictly express business should not be carried on by an interurban line, except so far as transporting express matter in the same manner as the old express companies carry on their business, with the help of the

steam roads. Electric express companies have been formed along these lines, and are carrying on a successful business. The interurban road, meanwhile, carries on its own freight business.

Two classes of freight are frequently established; the light, and the heavy, or carload lot. Light freight is carried as is express, in motor cars built for the purpose, and geared to a speed equal to that of passenger cars, so that they maintain the passenger schedule without interfering with it. On account of the limitation of power supply, heavy, bulky freight should be handled in powerful low-geared freight cars, also capable of hauling several standard steam freight cars in a train. This service is usually handled between midnight and morning, provided, of course, that it cannot be conducted at a more convenient time of the day without interfering with the passenger schedule. Up to the present time, most of the interurban lines have been practically limited, in the amount of freight handled, to that which is produced and consumed along their own lines of road.

The almost universal disposition of the steam roads in the past has been not to interchange or way-bill their freight cars over the electric roads. In Ohio and Pennsylvania, the two states in which this opposition has been the strongest, the interchange of freight in bulk with electric roads is rapidly increasing and considerable business along these lines is the result.

Some idea of the amount of freight and express business, in certain localities in New York State, can be seen in the following data for the year ending June, 1903.

	Gross Receipts. Freight & Express.	Car Miles.	Receipts per Car Mile. Cents.
Albany	$37.936	49,797	76
Rochester	28,381	46,764	60
Newburgh	12,881	16,516	78
Hudson Valley	22.190	54,842	40
Brooklyn Heights	75,658	189,494	40
Buffalo	89.354	219,672	41

The freight business of the Ohio and Michigan interurban lines has probably been developed and perfected further than elsewhere at the present time.

For the year ending April, 1903, the following figures were obtained:

	Gross Receipts. Freight.	Express.	Total.
Eastern Ohio Traction	$44,000		$44,000
Toledo & Western	23,000		23,000
Cincinnati, Georgetown & Portsmouth	37,500	$10,200	47,700
Cleveland & Southwestern	10,000	7,200	17,200
Lake Shore Electric	26,200	4,700	30,900

It is probable in the year above mentioned that the average annual gross receipts per mile of track did not exceed $750 for freight and express traffic.

The question as to whether interurban roads should handle express matter in a combination passenger and baggage car is one that depends entirely on local conditions. In certain localities, especially where competing for passenger traffic with steam roads, it is usually necessary to carry baggage, though not on every car. If baggage is carried it is often practicable to carry on a light express business, either by the road, or by a separate express company, provided the volume of the business does not interfere with what is considered a desirable passenger schedule. Traffic laws in certain states necessitate the carrying of baggage with the sale of a passenger's ticket.

The Utica and Mohawk Valley Railway Co., which operates a combined freight and express business, gives the following figures for the express and freight department for the year ending June 30, 1904:

Gross Receipts	$36,187.96
Operating Expenses	$22,177.24
Cost of power and interest on investment	$4,557.91
Net Income	$9,452.81
Total tonnage (tons)	8,604.
Average rate per 100 pounds (cents)	21.03
Gross earnings per express car mile per day (cents)	41
Earnings per car hour	$4.27

Regarding the proper classification of freight and express, and what to make the rates, it seems to be the general opinion that special classifications and rates should be made to fit local conditions. It is rare that exchange of traffic is made with foreign companies, but, if so, the "official classification" of the steam roads and express companies should be adopted with

modifications. In few cases should rates be made less than those of competitors, and some believe in a flat rate, with no classification.

On some interurban lines both freight and express are handled in the same cars, which are capable of high speed. This often results in a full carload, which, without freight, would be run at a loss. The sole difference between freight and express in this case is, the former is received and delivered at terminals only, and at a slightly less rate, while express is collected and delivered by wagon.

On lines running through farming districts the carriage of milk is frequently profitable. Milk stations, with platforms the height of the car floor, should be established at intervals. Charges of from 1 to 1.5 cents per gallon, dependent upon distance hauled, and including the return of the empty cans, is the usual rate.

But the freight and express business on interurban roads is in its infancy when we consider the volume of business now carried on compared with the large mileage on which this traffic has not yet been developed. It is the general impression that the interurban road is essentially a passenger-carrying road. Even if this is true at the present time, is that any reason to assume that it will always be? Consider the history of the steam roads, and we find that while freight receipts were once a small portion of the total, now they exceed the passenger receipts on all but a few roads.

Not many managers of interurban roads fully appreciate the profit with which an express or freight business (call it by either name) may be conducted over their lines if carefully worked up and well organized. To be sure, sometimes local conditions are decidedly unfavorable, but in general it ought to be feasible on an interurban road connecting a number of towns to a large city terminal and on suburban lines radiating from a city. The operation of an electric express service reaching out from a city in several directions to smaller centers of population which lie within a radius of 20 or 30 miles would do much toward increasing the volume of business done by the merchants of the city.

In establishing such an express or freight service, where there is competition with steam roads, prospective patrons

should be impressed with the advantages of quick delivery and every effort should be made to attain it. A sweeping reduction in prevailing rates is usually a mistake, for a rate equal to, or a little less than that of the competitors can be reduced later on with profit, but rates can seldom be increased without loss of business. Electric-express service is not cheap, but it is quick.

Sufficient equipment in the shape of motor freight cars and trailers should be provided to handle all the business offered without any delay. Too much care cannot be given to the erection of freight stations and platforms. These should have floors at the level of the floors of the freight cars. This not only enables train crews to handle the freight easily and quickly, but leaves it where it is convenient for transfer men to load on their drays. Careful attention should be given to requests for sidings from manufacturers along the line, especially where carload shipments are to be made and, where the road is in a position to handle such business, the sidings should be provided if sufficient business is assured.

As for carload lots, it has been said that an interurban road having a passenger traffic necessitating a half-hour schedule on single track, should leave such business alone. It is true that it could not be handled, at least in trains of several cars each, during the hours that such a passenger schedule is in effect, but some roads do handle such freight at night and with success. On account of the limitations of substations and power stations, most of the present interurban roads are not suited to hauling heavy freight trains, although short trains made up of standard steam railroad freight cars can easily be handled when occasion demands it. In few, if any, instances, has the freight business of an interurban road grown to the point where long, heavy freight trains are necessary. A great deal of freight in carload lots can be handled without bunching these cars into long trains. But the moment that freight trains begin to get so heavy as to seriously overload the substations, which means a large additional investment in power apparatus which remains idle most of the time, then it is necessary to split up the trains into smaller units, or buy a steam locomotive, as some have done.

But where passenger service is frequent it has been demon-

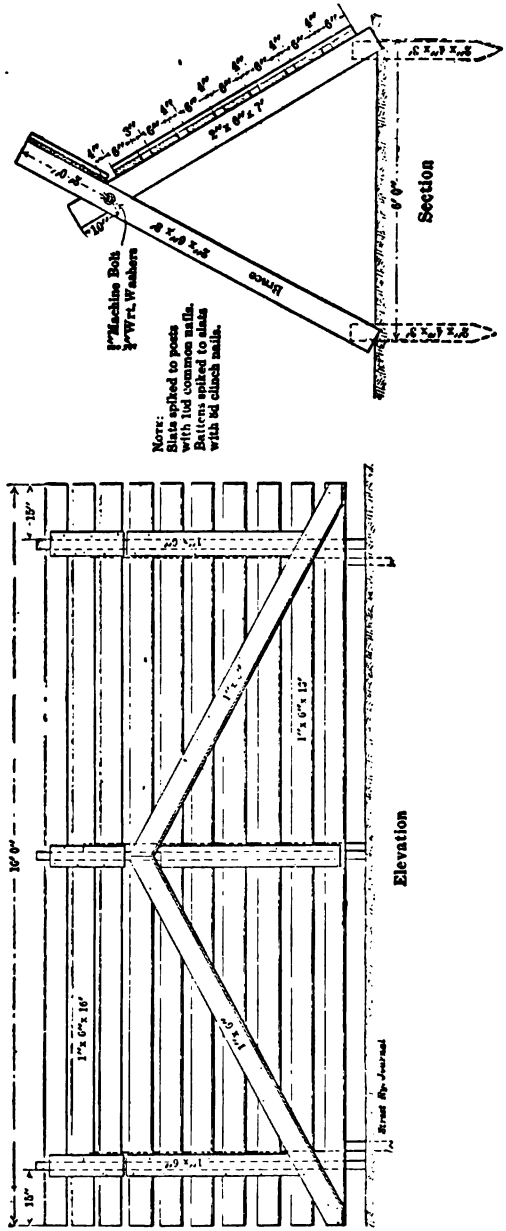


FIG. 206.—Snow Fence Adopted to Use on Interurban Roads.

strated that considerable business in the way of light fast freight and express can be done by using cars which can make the passenger schedule. Such cars often earn an average of 30 to 75 cents per mile, or $25.00 to $40.00 per day.

Handling Snow

In the northern and middle states snow removal is one of the most serious problems the manager of a city and suburban road has to contend with. In the beginning the magnitude of any snowstorm is unknown and the possibility of a tie-up of the lines is always imminent. Many a strenuous time has been experienced by officers and employees in the operation of snow plows and sweepers, for hours at a time, with little or no chance for rest until the storm abated.

The equipment used by the various roads for snow fighting consists of the sweeper, the shear plow, the nose plow and the rotary plow. The sweeper usually has two revolving brooms driven by motors, with their axles at an angle of about 45 degrees with the track. The shear plow is used on double track and has a large straight plow at an angle with the track, and considerably longer than the width of the track. It moves the snow all off to the right-hand side and consequently does not throw any on the opposite track. The nose plow is the ordinary pointed plow, and is used on single track, throwing the snow off on both sides. The plows are made of heavy sheet steel and arranged to raise and lower vertically, by either hand or compressed-air power. The rotary plow is practically the same as that used by steam roads, except that it is driven by electric power. The revolving fan, or propeller, is incased in steel at the sides and top, and on being forced into the drifts, collects the snow and discharges it out through a chute near the top of the casing, and throws it clear of the track.

Custom varies somewhat as to the proper equipment, depending upon the locality and climate. Some cities, as New York, depend largely on the sweeper, and employ large numbers of them. Others use the different forms of plows, sometimes followed up by sweepers. The rotary plows are seldom used in cities, as they are better adapted to suburban or interurban lines, where heavy drifts are liable to be encountered. Track

FIG. 207.—Motor Car Equipped with Steel Plow.

scrapers fitted to each passenger car are of great value, especially in the early hours of a storm in cities.

The main point in snow fighting is to keep all the cars moving, and on schedule time as long as possible. The least de-

Fig. 208.—Track Scraper.

lay gives the snow a chance, and a blockade is liable to result. The only way to keep a road open is to use every effort to se-

Fig. 209.—Electric Sweeper for Heavy Drifts.

cure the continual movement of both cars and plows, throughout the storm. Most large systems have special men assigned to

snow-plow work, who are instructed to report for duty on the approach of a storm, as soon as they are relieved from their regular car, or are called from their homes. The work is sometimes in charge of the mechanical department, and sometimes under the operating department. The latter plan is usually the best, and is steam road practice. Not infrequently a steam road is tied up by a snowstorm, while the neighboring interurban line is in operation. The reason is nearly always because of the scarcity of trains on the steam road, while the interurban cars pass over their line every 15 or 30 minutes.

FIG. 210.—Electric Sweeper for City Service.

Snow fences, in a portable form, have long been used by steam roads, and many interurban roads have adopted them. When placed near exposed portions of the line, or above cuts where drifts are liable to form, they afford much protection by causing the drifts to form about them instead of on the track. (See Fig. 206.)

A number of interurban lines use pilots on their passenger cars. If plows are substituted for these in winter, or the pilots converted into plows, the necessity for employing regular plows can frequently be overcome. Fig. 207 shows a heavy motor car equipped with steel plows beneath the platforms, attached to the car body, and arranged to raise and lower. They have a short stiff broom attached to the lower edge of the plow.

Such an equipment has frequently passed through snowdrifts with no difficulty, which stalled a steam locomotive. Regular plows are never needed when they are in use.

The records of the amount of snowfall in the principal northern cities between St. Louis and Boston, for six years prior to

FIG. 211.—Nose Plow for Single Track Work.

1904, show Buffalo to have the heaviest, with Rochester, Syracuse and Albany nearly as much. The winter of 1903-04 was unusual, for the snowfall exceeded that of recent years by

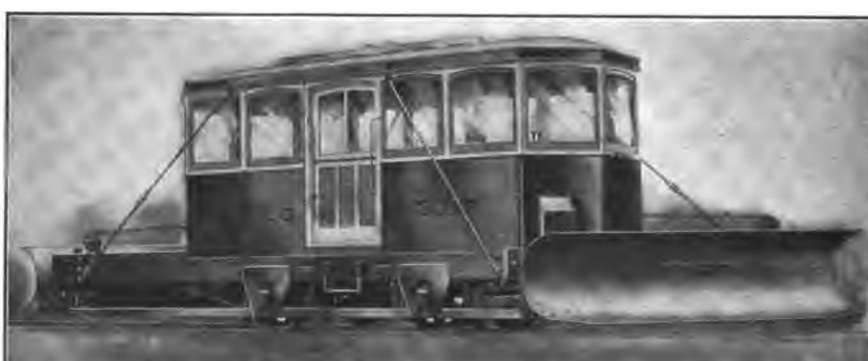


FIG. 212.—Shear Plow for Double Track Work.

about 50 per cent. The cost of snow removal is an important item, especially in a city system. The city authorities usually require the railway company to keep its tracks and two feet outside clear, and where the snow has to be removed from the

streets, as it has in most of the business streets, the company is expected to bear a share in this expense. Sometimes the company assists by carrying off the snow in cars. An idea of what the cost of snow removal is can be seen in the following table:

	Average of Six Years Ending June 30, 1903.	1903–04.	1904-5 to Mar. 1
Boston Elevated	$374	$633	$...
Worcester Consolidated	77	94	...
Springfield Street	96	173	140
State of Massachusetts[1]	112	212	...
New York City[2]	211	452	720
New York & Queens County	94	69	108
United Traction, Albany	100	138	80
Syracuse	58	113	55
Buffalo	[3]77	[4]127	...

[1] This includes all the lines in the state.

[2] Average of lines operated directly by Metropolitan Street Railway Company and New York City Railway Company.

[3] Average of International Railway, Buffalo Railway and Crosstown Railway.

[4] Average of International Railway and Crosstown Railway.

The cost to the Rochester Railway Co. during the winter of 1903-04 was $.0033 per car mile run during that year. The Syracuse Rapid Transit Co. expended $.0021 per car mile, and the interurban road known as the Utica and Mohawk Valley paid $.0046 per car mile. Figs. 208, 209, 210, 211 and 212 show a track scraper, sweepers and various styles of snow plows.

Tickets, Cash Fares and Transfers

The well-known fact that all men are not thoroughly honest from the lowest to the highest station in life, constitutes one of the chief reasons why so much time and thought has been spent by railway companies in the endeavor to formulate a system which will adequately protect them against loss in the handling of their tickets, cash fares or transfers. The losses cannot all be ascribed to employees, for the public must be guarded against as well. The old idea that it is a fair game to avoid paying fare on a railroad car if possible, or to defraud the Government out of its just dues by dodging the duty on imports still obtains, and probably always will. The lady who

sought the conductor before leaving the car in order to pay her nickel, which he had omitted to collect, caused a laugh among the passengers. There are few like her, but if all were the conductor's position would be far less difficult than it is. Many passengers will take a seat in a car with their fare in a convenient place, but seldom is a move made to give it up, even when the conductor is close by, until he makes the direct request.

The company expects the conductor to get all the fares when possible to do so, and when his fares, or register, do not properly correspond to the number of passengers, he is compelled to select someone whom he thinks has not paid, and request it. If he is right in his surmise nothing is said, but if he is mistaken he gets a gruff answer and a look which says he must be a green man to make such a mistake.

The recording of all fares on the register, especially in city service, protects the company to a large extent against losses through dishonest conductors. When cars are not crowded the passenger has become so accustomed to hearing his fare rung up that an omission to do so frequently attracts attention. One manager, when asked if it was his custom to employ men to ride on the cars to watch and check the conductors, replied in the negative, saying "the public were his best detectives." On crowded cars it is very difficult to detect a failure to record fares by the conductor, for he often fails to get them all, try as he can. Moreover, if someone is watching him, the watcher is usually on the crowded car.

Apart from these small peculations the opportunity to defraud the company of large amounts through the dishonest use of transfers or tickets has been so restricted by the different systems now in use, as to render it practically impossible without the co-operation of several conductors or motormen. Sometimes this is done on quite a large scale and extensive losses have resulted before detection. But the necessity of having a confederate in such dealings always acts as a strong deterrent to the man who contemplates it, for fear he may expose him.

The fare register in its various forms is about the only appliance which has been generally adopted as a safeguard by the street railways of this country. Inventors are continually at

work on improved registers, some of which provide for ringing up transfers, tickets or cash fares separately, and others are arranged to record the exact amount of fare paid by a passenger up to 25 or 50 cents, and even automatically compute the totals of the run like the well-known cash register. These latter check up errors made by conductors in reading the register. That all registers fail to afford the protection needed is well known, but their use is a necessity until some better system is offered. On many roads will be found men who are constantly studying how the register can be beaten to their own profit. The advent of a new type of register is always followed by an investigation and discussion of its merits by the men, and always with a view of discovering its weak points if it has any, but this does not indicate dishonest motives by any means. It is simply the natural desire to find out things.

It has been said, and rightly, too, that the only system in which the company gets all the fares, is that employed by the elevated and subway railways, where a ticket must be bought and given up before entering the train. This is practically impossible on a surface street railway, but the nearest approach to it has recently been described. It is the method of fare collection generally used in Canada, and is interesting, if not practicable in all our great cities.

One form of it is the so-called "coffee-pot" collection box. It is a small, two-compartment bank or safe with a slot in the top for receiving the fare, and is carried by the conductor. It is constructed entirely of steel covered with leather, and measures $8\frac{1}{2}$ inches x $5\frac{3}{4}$ inches x $2\frac{1}{2}$ inches, with a handle at one corner. The upper compartment contains a small glass window through which the conductor may see the coin or ticket before he pushes a button and opens a trap which drops it into the lower compartment. It is impossible to remove the contents of the box except with the key held by the authorized person at the main office. Fig. 213 shows how this box is used.

Each box is numbered and issued to the conductor empty, the proper records—conductor's number, car number, etc.—being taken. They are returned by the conductor at the end of his run to the car-house foreman, and are collected by a special car and taken to the office. It is clear that the company gets

all the fares paid by the employment of this system. It seems impossible to beat the box. The conductor is provided with sufficient money to make change, which he is supposed to do with his right hand, while he carries the box in his left. In addition he must run his car and manipulate the signal cord. Generally speaking his hands are pretty full, and no record is at hand of any passenger having made off with the box. In certain parts of some of our cities the latter temptation would be considerable.

Another form of this system is in use experimentally in Montreal, which has certain advantages over the other if the popu-

FIG. 213.—"Coffee Pot" Collection Box.

lace take kindly to it. Cars with roomy rear platforms are provided with two railings and two doors, one for entrance and the other for exit. There is also a door for exit only, on the front platform. The conductor stands on the rear platform between the doors and the fare box is fastened to the railing directly in front of him. Fig. 214 shows the arrangement clearly.

The passengers must all pass the conductor and the box before entering the car, and those who ride on the platform are where the conductor can see them. The box is presumably securely fastened, otherwise it would not be prudent for the con-

ductor to leave the platform to throw switches or attend to other duties, in an emergency. The cars are called "pay as you enter" and signs are carried on the front or sides of the car, admonishing prospective passengers to have their fare

FIG. 214.—"Pay as You Enter" Car.

ready, with the object of educating the public in facilitating quick entrance.

This is one of the principal points on which its success or failure would depend, if introduced in one of our larger American cities. During "rush hours" it would be almost certain to create serious congestion in the rear platform when a large number of people attempt to board the car under our present conditions. The necessity of holding the car until

a sufficient number had deposited their fare to leave room enough for the remainder to stand on the platform would cause such a delay as to seriously interfere with the regular movement of the cars. That the average citizen can be educated to sensible changes, when their object is apparent, has been proved more than once. However, where traffic is very dense, any innovation which causes a delay in entering or leaving the car should be introduced with caution.

To the uninitiated the use of transfers to any considerable extent would seem to imply a loss to the company because of the substitution of the transfer for an additional cash fare. This, however, has not been found to be true except in rare instances. The company should guard itself against loss by careful study of the conditions, which differ in every city, and authorize the issue of transfers at such points as seem necessary to the public, and for the best interests of the company. Many persons bound to points on branch lines will prefer to walk from the junction point rather than pay an extra fare. The issuance of a transfer in such cases is an advantage to the company in that it increases travel, on both the trunk line and the branch. In most of the large cities the use of transfers at nearly all connecting points, is general practice. They are issued in such a way that a passenger may travel in one general direction, but not so that he may return over any other line to the vicinity of the starting point. The giving of another transfer on receipt of one, thus allowing a ride over three or more lines for one fare, is not often allowed. Most companies are decidedly against the practice, for the reason that a ride over two lines for one fare is all the public should expect. In some cases there may be certain short lines connecting trunk lines, where the total length of the ride is not excessive, that it may be advisable.

Mr. Leon Jewell has published the following data of the Chicago City Railway Company, with respect to the operation of its transfer system, as representing the growth and development of the use of transfers over a period of twenty years—1884 to 1904:

	1884	1904
Number of distinct lines of cars operated	7	20
Number of distinct routes operated	19	182
Number of transfer points	2	94
Maximum possible number of transfers issued for one continuous ride in one general direction	1	19
Average number of transfer passengers carried daily	4,000	207,728
Percentage of transfer passengers to fare passengers	4.6%	50.7%
Percentage of transfer passengers to fare and transfer passengers	4.4%	37.0%
Average fare per passenger (fare and transfer passengers)	$0.0478	$0.0318
Length of longest line, miles	4.59	9.78
Average length of all lines, miles	3.38	5.37
Longest transfer route possible, miles	4.39	15.74

These figures afford an interesting analysis of the effect of the final introduction of a universal transfer system in a large city.

Fig. 215 illustrates a new style of transfer slip adopted by the Brooklyn Rapid Transit. Its chief point of difference from other styles is that the time limit is indicated by the tearing off of one end, rendering the use of a punch unnecessary.

The collection of interurban fares is an entirely different problem from that in city service, and many different systems are in use. As existing conditions are seldom similar it is probable that one system may be fairly well adapted to one road while it would not be appropriate for another. There are many cases where the simple extension of the city system is the one in use. This means that the line is divided into 5-cent zones, and the conductor collects and rings up the fare in each zone. Sometimes the labor involved in the above is reduced by the conductor ringing up the total fare to destination on an indicating register, and giving the passenger a receipt for the amount collected. The above methods are to be found on suburban roads rather than interurban.

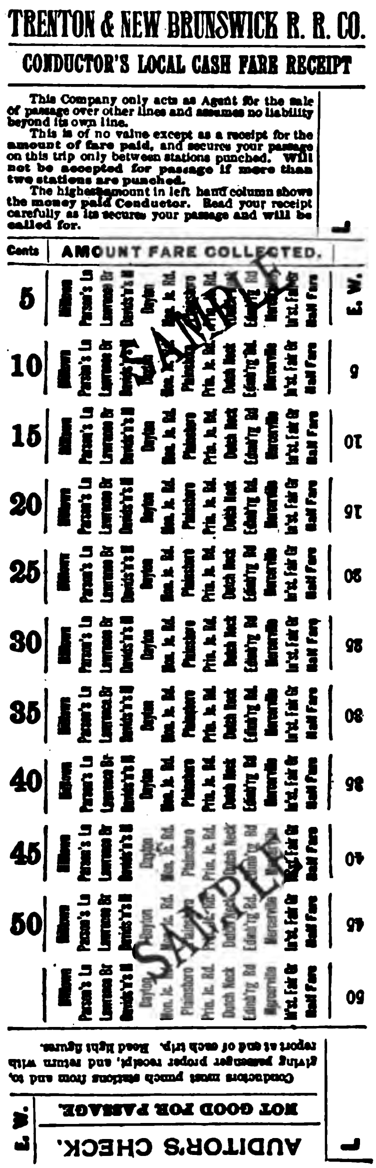
The purely interurban roads, those connecting a number of towns or cities, are now generally adopting some form of ticket. Because it is necessary to pick up passengers almost anywhere along the line, cash fares cannot be entirely avoided, but a well-devised ticket system similar, as far as possible, to the steam road plan, will greatly reduce the number of cash fares, for they are the principal source of loss to the company. The question

of ticket agents at once appears and whether their employment would pay. Tickets are sometimes sold by conductors on the car, but, where possible, this plan should be avoided. The employment of ticket agents does not necessarily mean that they must be installed in railroad stations built for the purpose, because the line passes through a street in the towns and space can easily be obtained in some store or other place of business where the sale of tickets may be carried on. In the smaller towns the work of the agent is so light that the proprietor of a store on the line can usually be induced to look after the ticket sales for a small compensation. There is little chance to defraud the company by anyone under such a system. All tickets

FIG. 215.—Style of Transfer Slip Used by the Brooklyn Rapid Transit Company.

issued to agents represent so much money for which an account must be ultimately given either in cash or tickets. Round trip tickets at a slightly lower rate than double the one way rate are the best form of ticket for any interurban road. They form an inducement for their purchase, lessen the number of cash fares and insure the traveler's return over the same road. Another reason why a ticket system should be used is, that a conductor can handle his business far easier than he can when a complicated system of cash fare registers is employed.

A good example of a method of handling local and foreign cash fares, and interline tickets, is furnished by a New Jersey interurban road which connects with a foreign road at both ends. Fig. 216 is a reproduction of the conductor's local cash



TRENTON & NEW BRUNSWICK R. R. CO.

CONDUCTOR'S LOCAL CASH FARE RECEIPT

This Company only acts as Agent for the sale of passage over other lines and assumes no liability beyond its own line.

This is of no value except as a receipt for the amount of fare paid, and secures your passage on this trip only between stations punched. Will not be accepted for passage if more than two stations are punched.

The highest amount in left hand column shows the money paid Conductor. Read your receipt carefully as its secures your passage and will be called for.

Cents | AMOUNT FARE COLLECTED.

5 10 15 20 25 30 35 40 45 50

Conductors must punch stations from and to, giving passenger proper receipt, and return with report at end of each trip. Read right figures.

NOT GOOD FOR PASSAGE.

AUDITOR'S CHECK.

FIG. 216.—Conductor's Local Cash Fare Receipt.

fare receipt. It is printed in blue ink on white paper. On payment of a cash fare the passenger receives one of these receipts, which has been torn off by the conductor so that the

TRENTON & NEW BRUNSWICK RAILROAD CO.

Form H-1. 300-8-02.

CONDUCTOR'S RATE SHEET

FARES BETWEEN STATIONS
AND FOR WHICH
CONDUCTOR'S CASH FARE RECEIPT
MUST BE ISSUED

FULL FARE RATES

	N. Brunswick	Milltown	Parson's Ln.	Lawrence Br.	Davids'n's M.	Dayton	Mon. Jc. Rd.	Plainsboro	Prin. Jc. Rd.	Dutch Neck	Edinb'rg Rd.	Mercerville	In'st. Fair Gr.	Trenton
N. Brunswick	★	★	15	15	20	20	25	25	30	30	35	40	40	★
Milltown	★	★	10	10	15	15	20	20	25	25	30	35	35	45
Parson's Ln.	15	10	★	10	10	15	20	20	25	25	30	35	35	45
Lawrence Br.	15	10	10	★	10	15	15	20	25	25	30	30	35	45
Davids'n's M.	20	15	10	10	★	10	15	15	20	20	30	30	30	40
Dayton	20	15	15	15	10	★	10	15	15	20	25	25	30	40
Mon. Jc. Rd.	25	20	20	15	15	10	★	10	15	15	20	25	25	35
Plainsboro	25	20	20	20	15	15	10	★	10	10	20	20	25	35
Prin. Jc. Rd.	30	25	25	25	20	15	15	10	★	10	15	15	20	30
Dutch Neck	30	25	25	25	20	20	15	10	10	★	15	15	20	30
Edinb'rg Rd.	35	30	30	30	30	25	20	20	15	15	★	10	10	20
Mercerville	40	35	35	30	30	25	25	20	15	15	10	★	10	20
In'st. Fair Gr.	40	35	35	35	30	30	25	25	20	20	10	10	★	★
Trenton	★	45	45	45	40	40	35	35	30	30	20	20	★	★

Local Cash Fare Receipts must be issued where rates are found INSIDE heavy black square.

Foreign Cash Fare Receipts must be issued where rates are found OUTSIDE heavy black square.

FIG. 217.—Conductor's Rate Sheet.

highest figure in the left-hand column shows how much was paid. The conductor must return the other half to the office and the highest figure in the right-hand column shows how much he collected. The foreign cash fare receipt is printed in

FIGS. 218 and 219.—Samples of Interline Tickets.

red ink, on white paper, and is retained by the passenger until he gives it up to the conductor of the foreign road who accepts it as a ticket. The interurban road afterwards redeems these cash fares, paying the foreign roads the amount agreed on. These cash fare receipts are exactly alike except as to the color and title. The stations from and to which fare is paid are punched on both the passenger's receipt and the stub retained by the conductor. Fig. 217 shows the conductor's rate sheet, which indicates to the conductor that where cash fares between certain points fall outside the heavy black square he is to issue a foreign receipt, and when they are found inside the square a local receipt. An exceedingly simple arrangement.

Figs. 218 and 219 are samples of interline tickets which are similar to those used by many steam roads.

The Management and Discipline of the Men

The conditions governing the relations between a railway company and its men on the largest systems differ somewhat from those on a road of average size, because the greater number of men necessitates the employment of a number of subordinate officials who must stand between the men and the real management, but the principle involved is the same.

On the average road the superintendent, rather than the manager, is in direct contact with the men, and on the former depends chiefly what those relations shall be.

He should possess executive ability in a marked degree to be successful, and his natural personal characteristics must be such that he can sustain more or less intimate relations with the men without loss of dignity. He must know them all personally, stand by them and respect them as gentlemen on all occasions. It has frequently been demonstrated that such a policy resulted in the popularity of the superintendent, and at the same time enabled him to maintain strict discipline.

In many cases the principal reason why the men organize and form a union is because of a dislike of their superior officer, or what they consider unfair treatment at his hands.

On every road the men may be divided into two classes—the young men who have no family ties, and the men of family with homes to maintain. The supposed unfair treatment is often

nothing but the exercise of necessary discipline over the younger men, the older rarely require it. Some of the men may consider trifling such offenses as entering a saloon at one end of a run while awaiting their leaving time, or smoking while the car is empty and running through outlying districts, but such violations of the rules should be suppressed with firmness, on account of the example it creates, and the effect on the public. There are many other small offenses which, if allowed to continue, will tend to destroy all discipline, and cause a certain feeling of contempt among some of the men for their superior officers. At the same time it is quite possible to enforce the necessary discipline in a manner which is firm without being offensive.

There is no fixed method of maintaining good discipline, but the man in charge must know the railroad business throughout, especially the details of construction, operation and maintenance. He must have the implicit confidence of his men, and the reputation of being shrewd, honest and perfectly fair in the performance of his official duties. Executive ability implies a faculty for organization which is one of the greatest attributes to good discipline. Every man in the company should be made to thoroughly understand the service he is expected to give, and exactly what rank he holds.

Some roads run on year after year without any trouble with the men as a whole, and if the latter are asked the reason they will almost invariably reply that they are satisfied with their treatment and believe their superintendent to be a fair-minded man who always regards them as men, and only calls them to account for infractions of the rules when they deserve it. They may also add that no favoritism is shown and all stand an equal chance for promotion.

Many of the smaller roads at the present time require their men to remain on duty 12 or 13 hours a day at an hourly rate of 11 to 16 cents. Frequently, on special days, they are asked to work 16 or 18 hours with no extra compensation for the overtime.

As a matter of fact it is the business of the management to get as much as they can from the men for the least pay, for it may be said that the stockholders, through the board of directors, demand it. In such circumstances there are usually

evidences of bad or incompetent management. The equipment is running down because there is not a sufficient amount allowed for maintenance, both in the matter of supplies and efficient workmen. The men are generally discontented, and take little interest in their work or the prosperity of the company. Rarely will good men stay on such a road unless compelled to by force of circumstances. The end is invariably reorganization and a change in the management.

Is it to be wondered at, under such conditions, that the men organize for their own defense and form a union? The management then has to face an entirely different state of affairs. They are usually first asked to recognize the organization, by which they are supposed to acknowledge that there is a union, consent to its existence, and receive and treat with a committee ostensibly representing all the men, when frequently only about 60 per cent. of them have joined. Upon the answer to this question a good deal often depends. It should be given the most careful consideration as regards local conditions, the probable effect in the future, the practicability of securing new men, the means for protecting the property of the company, and most important of all the probable attitude of the general public in the event of a strike.

If the past policy of the road and its manner of accommodating the public have been unsatisfactory to the latter, a refusal to grant the recognition demanded, if deemed advisable, should be made with the full knowledge of the influence of an adverse public opinion. If the public sympathizes with the men in a strike, the former are a far more formidable opponent than are the men themselves, and in many cases are chiefly instrumental in determining the final outcome. By the public are not meant those sympathizers, who may or may not be members of other labor organizations, a number of whom are often responsible for much of the violence attending a strike, but the citizens, the public press, and the business men as a whole. In many instances, in cases of this kind, it will be found the wisest policy to give the men the recognition they ask.

There is little to be gained by actively opposing organization. The men have the right to organize and, if their leaders are intelligent and capable, they are often able to better conditions

by stating their case fairly to the management, who in turn give them the view of the case from the company's standpoint. This often brings about a state of harmony eminently satisfactory to both sides. On the other hand, if the leaders of the union are not really competent men, and if the meetings are controlled by the votes of the younger element who in some instances would welcome the excitement attending a strike, the organization of the men has failed in its legitimate purpose, and disturbed conditions ensue, for which there is little excuse and which surely work to the disadvantage of the men in the end.

If in a case where the men have asked recognition, it has been thought best to grant it, other demands are usually made sooner or later. These most frequently consist of a request for an increase in wages, or a reduction in the hours of labor, which is the same thing. If either of these demands are granted it means an increase in operating expense. With this fact in mind a careful consideration of the situation, after a conference with the committee representing the men, should be made. If it should seem to be for the best interests of the company to make a slight concession in one or both these demands in the direction of a readjustment of wages and hours of labor, the decision is generally based on wages paid on nearby roads, on local conditions generally and especially on the financial state of the property.

Any demands for the discharge of non-union men, or that union men only shall be given employment in the future, should never be granted. This is far too near an approach to the state of affairs where the men presume to direct the management. Some of the best-managed railway brotherhoods in the country have declared that only the "open shop" principle is applicable to railway employees, and in this they are right, as experience has proven. A railway employee should always be free to join a union or not, as he pleases, and if he does not the management should see that his interests are protected and that he is allowed to perform his duties without interference from his organized fellow employees.

It is a recognized rule of the best railway employees' organizations that a strike is to be carefully avoided until, according to their views, there is no alternative, as history has shown

that any benefit to either side of the controversy has rarely resulted from them.

In presenting their demands the men seldom expect to have them all granted. The smallest concession on the part of the company will often be sufficient to avert all trouble. Far too often are local organizations of the men ruled by incompetents, and their influence is hurtful to their cause. On the other hand managers are frequently careless or blind to the conditions surrounding their men and fail to see the slightest justice in their demands. As one manager remarked: "Our road is profitable, we can afford to shut down for two weeks or a month and see how they like that." He apparently ignored entirely the power of public opinion.

It is greatly to be regretted that street railway strikes in the past have nearly always been accompanied by scenes of violence and by the destruction of the company's property. Probably much of the damage has been caused by so-called sympathizers who were not in the employ of the road. The union generally cautions its members against violence, or the instigation of it, but the control of all its members in such times is an impossibility.

An extract from the decision of the anthracite coal strike commission of 1902 voices the opinion of the highest authority on the rights of an employee which is as applicable to the street railways as to the coal mine. It is as follows:

"The right to remain at work where others have ceased to work, or to engage anew in work which others have abandoned, is part of the personal liberty of a citizen that can never be surrendered, and every infringement thereof merits, and should receive, the stern denouncement of the law. All government implies restraint, and it is not less but more necessary in self-governed communities than in others to compel restraint of the passions of men which make for disorder and lawlessness. Our language is the language of a free people and fails to furnish any form of speech by which the right of a citizen to work when he pleases, for whom he pleases and on what terms he pleases can be successfully denied.

"The common sense of our people, as well as the common law, forbids that this right should be assailed with impunity. It is vain to say that the man who remains at work while others

cease to work or takes the place of one who has abandoned his work helps to defeat the aspirations of men who seek to obtain better recompense for their labor and better conditions of life. Approval of the object of a strike or persuasion that its purpose is high and noble cannot sanction an attempt to destroy the right of others to a different opinion in this respect, or to interfere with their conduct in choosing to work upon what terms and at what time and for whom it may please them so to do."

On some of the largest and best managed street railway systems the men have never organized and show no inclination to do so. This condition has been invariably due to the careful attention given by the management to their welfare. They are well treated, well paid, and length of service means increased pay and additional privileges. The extent to which this welfare work is being carried is well illustrated by the recent action of the United Railways of St. Louis. A clubhouse is being planned, and a loan fund has been started. Employees can borrow from this loan fund without fee or interest to the entire amount of their indebtedness. They can then repay the loans in small installments. Employees of the road can become members of the hospital association by paying 50 cents a month. Two fifteen-room residences have been purchased and are being converted into modern hospitals. Men injured on duty, who are members of the association, will receive treatment free and $1.50 a day besides, while they are unable to work. Men injured when not on duty will receive treatment and 50 cents a day. The company recently purchased an old mansion, which is being fitted up as a clubhouse, and will be accessible to all employees of the company. A brass band will be organized, and the members furnished with instruments and uniforms. A plot of ground will also be fenced in to be used for ball and other outdoor games.

What the average road needs above all other things is a superintendent who knows his business, and a man of ability he must be to hold the respect of his men. He should not be unwilling to listen to their suggestions regarding the operation of the road, for oftentimes they have ideas which may be of value to the company. A bow and a pleasant word on meeting them on the street, goes a long way toward building up good

feeling. It is unnecessary that he should have been one of themselves, risen from the ranks, but he should be able to view matters from their standpoint as well as from that of the company, and while he should be firm in the exercise of his authority for lapses of duty, under no circumstances should he reprimand an employee on duty in the presence of passengers or of his fellow-men.

"All things considered, the position of a conductor or motorman on a large city system is no sinecure. The work to do is often exceedingly trying, mentally and physically. They suffer from the indignation of every hot-tempered individual who considers himself abused, and from the vagaries of every crank dissatisfied with the conditions under which he lives. Too frequently a peppery man or woman blames the innocent motorman or conductor for faults of the corporation that employs him, for which he is not responsible in any way. If a line is blocked, if a car is delayed, or if the service is inadequate, the conductor must listen to exasperating remarks in silence. If a motorman neglects to stop for a would-be passenger, the crew of the next car is sure to catch it. If the motorman stops for all who want to ride, the passengers already aboard begin to growl at the delay. In more serious cases, when a venturesome child, trying to see how long he can remain on the track without being struck, miscalculates and is run down, the blame is always put on the motorman, and sometimes a coward in the crowd tries to incite an attack on him. Under such conditions the railway employees work, most of them holding their tempers, restraining their desire to 'talk back,' assisting passengers when they may and making generally a most creditable attempt at it."

The following abstract from an open letter written by the management of the United Railroads of San Francisco to the men is a remarkably concise, well expressed statement of the relations expected to be maintained between the company and their employees:

To Applicants and Employees: The chief requisites necessary to obtain employment and to retain your position are these:

First: You must be honest. The dishonest man cannot continue long in any service.

Second: You must be patient and polite to the public. The

company realizes that frequently passengers may be unreasonable in their demands or exasperating in their manner, and that at times it will require an effort on the part of the employee to refrain from resenting what appears to be an insult or a lesser imposition. But the ability to control your own temper is one of the very necessary qualifications of the service.

Third: You must never lose sight of the fact that your recklessness, your carelessness, or your negligence may render you responsible for the loss of a human life. Never take a chance.

Fourth: Observe strictly the general rules of the company. They have been carefully drawn to protect life and property, and to give the public the best possible service. The employee who observes the four cardinal rules above set out may feel assured:

First: That he may have continuous employment with this company. That he is as much a part of the company as are any of its officers.

Second: That no political or outside influence can unjustly deprive him of his position.

Third: That in making promotions the company will give preference to its most faithful and competent men where it is possible to do so. The highest position in the gift of the company is open to the qualified employee.

Fourth: Special meritorious acts by men with a good record will always be recognized.

The new employee on entering the service may find men who do not come up to the standard set out above, and he may believe that such delinquents are successfully deluding the company. The man who indulges this thought deceives no one but himself. The great majority of our employees are honest, capable, industrious men. There are some, as a matter of course, who are indifferent, but the new employee will discover that such men seldom last long.

The company is more than willing to deal fairly with its employees, and it demands in return that employees deal fairly by it. When the company takes you into its employ it is reposing special trust and confidence in you and those who have indorsed and stood sponsor for you, a trust which I hope the future will more than justify, and that you may ever stand on our records as honest, faithful, careful employees.

Electric Railway Accounting

The subject of accounting, except on the larger railway systems, has not been given the prominence it deserves. An accounting department for a road of average size is generally regarded as an appendage which would not be carried if it were possible to discover some way to get along without it. The capacity of the department for furnishing statistical information of the most vital importance for the guidance of the operating department is unknown to some and ignored by others.

It is commonly known as the bookkeeping end of the railroad business, and the proper accounting for income produced by ticket sales and cash fares, as well as the recording of bills payable, is the limit of the duties it is expected to perform. The common impression that it is not a revenue producing department is true in one sense, but decidedly erroneous if considered from a different viewpoint. A well equipped, well managed accounting department can be made to take as important a part in the revenue producing business of the company as any other department. The only difference in this respect between the accounting department and the others is that its revenue producing capabilities are indirect. Do not carefully prepared monthly reports on the financial condition of the company, together with statistics of operation, furnish a basis of information by comparison with past performances for the management by which they are able to decide intelligently as to the future methods to be adopted? When the effect of a certain policy in operation shows a marked increase in earnings or a decided falling off, as reported by the accounting department, is not that department an indirect assistance to revenue production by enabling the management to continue the one policy or discontinue the other? If the accounting department did not furnish this information, which is often of great importance to successful operation, who would?

Nevertheless it is a fact that on the majority of electric railways of average size, both interurban and urban, the only statistics the management seems to care for is a monthly statement of the gross earnings and operating expense. The accounting department of such roads could consist of one man

whose duty would be to count and record the daily receipts, from which he could arrive at the gross earnings and record the bills payable and the salary list, which labor and material furnish the operating expense. Instances are known where an interurban road operating six or eight cars was officered by a superintendent and a car starter only; there may have been a secretary and a president in a distant city, but they were but figureheads so far as operating the road was concerned. The accounting department of this road, as well as all the other departments, except the power station, was the superintendent, and he had no clerks, and the general consensus of opinion was that he earned his salary. But still another instance of a combined city and interurban road owning 23 cars with gross earnings averaging nearly $10,000.00 per month is entirely handled by a manager, a superintendent and a master mechanic. All accounting is done by the first two and no clerks are in evidence. Evidently statistical information for this road is sadly lacking.

The accounting of a large steam road is usually undertaken by four of five subdepartments known as the Purchasing, Passenger Receipts, Freight Receipts and Disbursing departments, all of which have their separate heads who report to the comptroller. The Treasury department is separate and under the treasurer. The average electric railway necessarily combines these all in the one accounting department, and the number of clerks or assistants required depends entirely on how much information the management desires, and often a change in management makes a considerable change in the size and importance of the accounting department.

All progressive managers wish to be supplied with certain statistical information each month. Sometimes the regular monthly report contains all the information desired, but often much information pertaining to the running of the operating or mechanical departments is desired in addition. The graphic method of presenting statistics should be followed whenever possible. Instead of being compelled to look over columns of figures to make the examination and comparison desired, this method gives the data reduced to curves plotted from two variables, one horizontally and the other vertically. A convenient form in which to keep such curves is a loose-leaf data

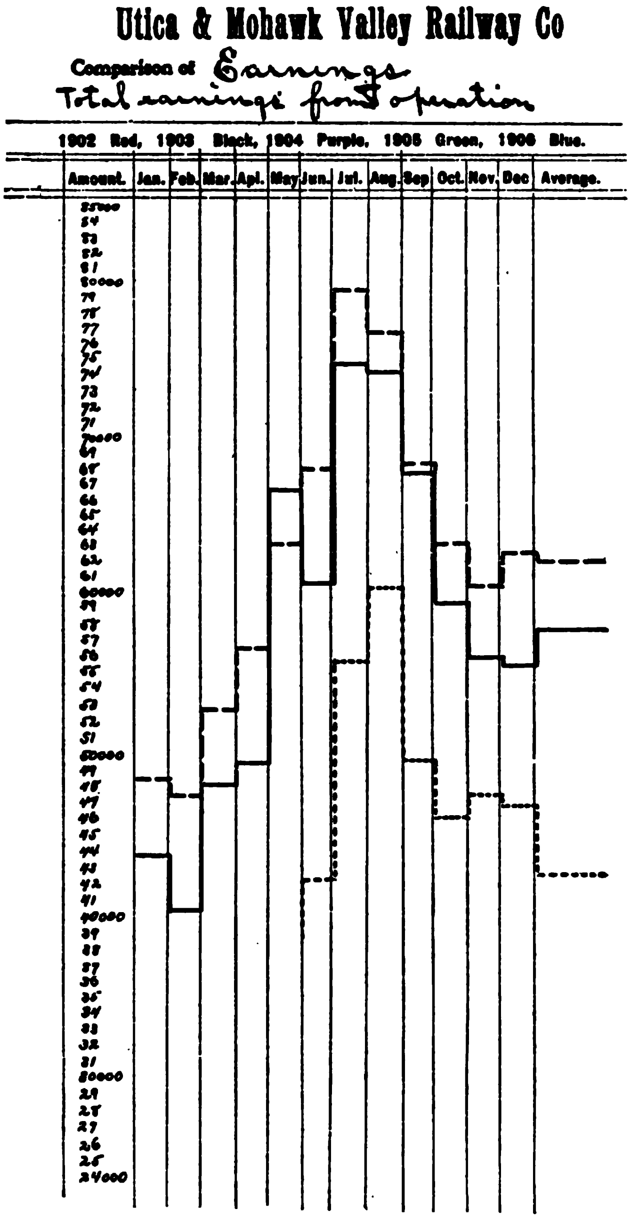


FIG. 220.—A Graphic Method of Compiling Operating Statistics.

book, the pages of which are about 4 inches x 7½ inches and ruled in cross-section. Fig. 220 illustrates one method. The amounts in the vertical column differ by $1,000 per division, and the horizontal divisions are months. Different years are compared on the same sheet by drawing the curves in colors or broken lines.

Fig. 221 gives another example of the use of curves showing the yearly variation in platform expense. In the same manner could be shown car mileage and car hours, operating expenses per mile and per hour, earnings per car mile and car hour, receipts per passenger carried, expense of maintenance of way, power station operation and output and a hundred other records. A comparison of car miles or car hours with operating expenses and earnings month by month for two or more years is possible on the same sheet. Some interesting facts are sure to be discovered.

So much has been said and written about the importance of a standard system of electric railway accounting that little can be added, but it is a cause for congratulation that almost every railway which does any accounting has adopted in full, or in part, the standard system of electric railway accounting devised and recommended by the Street Railway Accountants' Association of America.

Electrolysis and its Prevention

In the ordinary grounded system of continuous current power distribution employed by the electric railways in most of our cities, the current utilized by each car passes from the wheels into the rails, which are supposed to return it to the power station. But the rails are in contact in numberless locations with the moist earth which acts as a medium for conducting a portion of the current to the nearest water or gas pipe forming a part of the great network of pipes underlying the whole city. This portion of the return current follows the path of least resistance through the piping systems until it reaches the vicinity of the power station, when it usually returns to the rails which are directly connected to the negative bus bar. The total current from the cars divides between these two return circuits, the rails and pipes, exactly in pro-

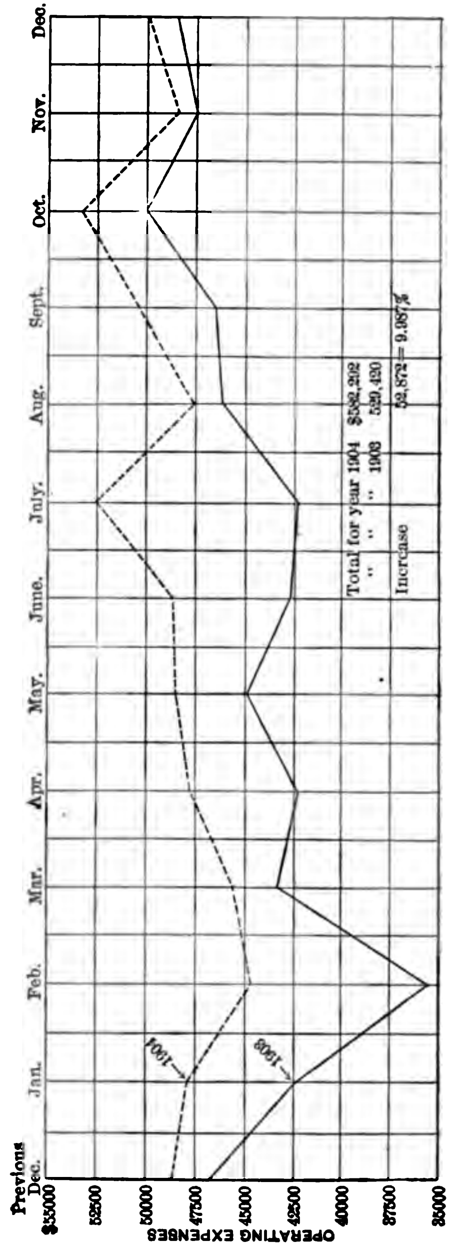


Chart No. 8.

Fig. 221.—A Graphic Method of Compiling Operating Statistics.

portion to the resistance it encounters in each. A thorough investigation of the various ramifications of the grounded current in a large city forms a most interesting study.

Electrolysis, as commonly understood, is the electrolytic action sometimes set up when a current leaves a metallic surface buried in moist soil. If the moisture is caused by pure fresh water, it may act as an insulator, and electrolysis will not take place; also if the current is of large volume, that is, if the density per unit of area becomes very great, electrolytic action practically ceases and the energy appears as heat. Certain characteristic appearances which occur on damaged metallic pipes are very difficult to identify as being caused by electrolysis. It has been found that similar conditions are also produced on metallic surfaces by the corrosive action of the soil alone. Water pipes laid along the roadbed of a steam road constructed principally of cinders have been known to suffer serious damage when no electric current was present. Similarly a water main entering a large city was damaged by the action of the soil alone.

In cases where pipes have suffered damage it is sometimes of the utmost importance to the railroad company, whose lines may be in the vicinity, to determine whether it is caused by electrolysis or by natural corrosion. One method for determining this has been used which is quite positive in results, but takes time.

The pipe is exposed for about 8 feet of its length. Two cast split sheaths or sleeves are made of approximately the same composition as the pipe. These are about three times as long as the diameter of the pipe, and are fitted around it. One is brought into good electrical contact with the pipe by cleaning and amalgamating, and the other is insulated by a sheet of rubber packing, or other equivalent non-absorbent insulator. A record of their weights is obtained before they are placed in position. They are then applied to the pipe, the earth filled in, the paving replaced and the whole left undisturbed for about six months. They are then removed and carefully cleaned by scrubbing with a bristle brush and crude oil. They are then dried and reweighed. If electrolysis has been present the uninsulated sleeve will weigh considerably less than it did at first. while the insulated one will lose but little. If electrolysis has

not taken place they will both lose about the same amount due to natural corrosion. Fig. 222 illustrates this test.

Conditions affecting the presence of electrolysis vary greatly in different cities. The relative positions of the principal power station and the pumping station of the water supply have a marked influence. When these two centers of distribution are close together there is less opportunity for electrolysis to occur. This is because the greater number and size of the water mains expose a much greater surface area, and they are able to give up to the rails a large volume of current per unit area without raising the potential to the danger limit. At the same time the area of the pipe surface continually decreases

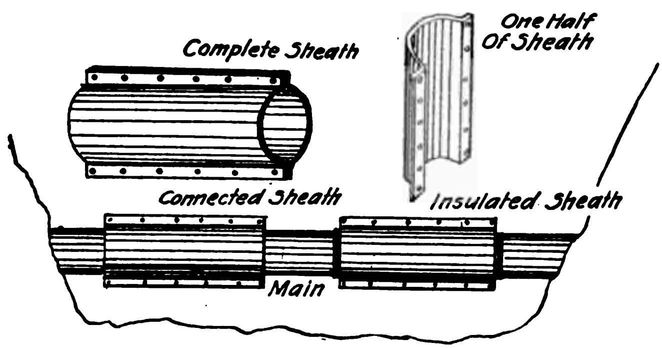


FIG. 222.—Method of Testing for Electrolysis.

in the outlying districts, where the current density in the rails is also at a minimum. Thus the normal resistance between the rail and the pipe is greatest at these points where the potential difference is at a maximum. Under these conditions in outlying districts, with fairly good bonding, there is little tendency on the part of the return current to take to the pipe.

It will be usually found, in a case like the above, that the potential differences found all over the system will average higher than one where the power station and source of water supply are widely separated. This would formerly have been considered as indicating the presence of, or danger from, electrolysis when high potential differences were the only means for predicting electrolytic damage. This was often misleading, for the reason that the higher the earth resistance the

greater the difference of potential that can exist between the rail and the pipe.

A pavement which is practically impervious to surface moisture, such as asphalt, brick or Belgian block, when laid on a foundation of concrete 4 inches to 8 inches thick, offers protection to underlying pipes. Under these conditions the electrolyte in contact with the pipe has not the circulation, nor is it replenished with moisture, as in an open street. It has been found that when the active materials in an electrolyte surrounding a pipe have been reduced the chemical action ceases, and will not be renewed until the voltage rises to approximately 1.5 volts between the surface of the metal and the electrolyte. At this potential water can be decomposed and the oxygen released oxidizes the metal of the pipe. The rate of depreciation of the pipe is reduced by the film of oxide formed on the surface of the pipe, for it seems to have a certain screening effect against the influence of the current flowing, and the actual metal destroyed after the pipe has received this film of oxide rapidly decreases with time and the continued action of the current.

It should be understood that the only potential which is active is that which exists between the pipe surface and the electrolyte immediately surrounding the surface. The difference of potential existing between the rail and the pipe does not always indicate the potential which may be found between the pipe surface and the electrolyte. The fall of potential along this path between the rail and the pipe depends upon the resistance of the surrounding earth, the resistance of the contact between the electrolyte and the pipe and the resistance of the paving. It is therefore evident that the normal earth resistance plays an important part in determining whether the potential at the surface of the pipe will rise to such a value that electrolysis will take place.

A method of testing this condition is as follows: The earth must not be disturbed around the pipe; the instrument used must not introduce a resistance into this circuit which would disturb the normal difference of potential that exists between the electrolyte and the pipe surface; and the test plate must not produce any local electromotive force which would disturb the true conditions. To accomplish this a cadmium plate may

be used for a test plate and the Poggendorf method of test followed. In this method the electromotive force to be measured is balanced against a known opposing electromotive force by means of an external resistance the value of which is known. Fig. 223 illustrates how the test is made. A small opening is made in the street over the pipe and the test rods driven down until one is in contact with the pipe, and the cadmium tip on the other rod is adjacent to the pipe. The connections are

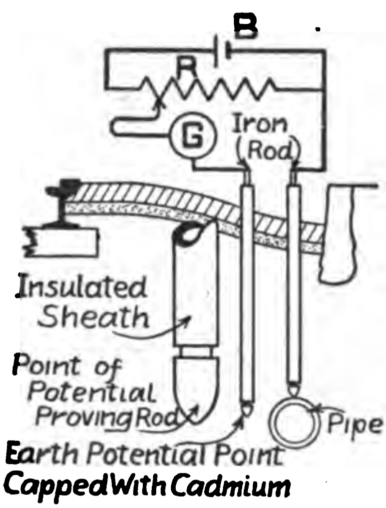


FIG. 223.—Method of Determining Potential between Pipe and Electrolyte.

then made as shown in the figure and the measurement of potential taken.

A frequent cause for electrolysis is found in cities through which a river flows. It is due to the fact that the systems of piping on both sides are usually connected by a few large mains passing beneath the river. The effect of this is to concentrate the current collected over large districts on these few mains, and trouble has occurred especially where the power station is located on the bank of the river near them. Here the current must be drawn from small surface areas of piping, and electrolysis may take place due to this concentration if proper remedial measures are not taken.

It should be the endeavor of all electric railway companies

to prevent, as far as possible, the escape of their current from the rails to the pipes. Engineers have applied a number of methods which have been successful in reducing the volume of these stray currents very materially. The first question that arises in an investigation of existing conditions is whether the current is being diverted from the rails to the piping system through any metallic contacts. In cases where pipes have been carried over steel bridges and are in metallic contact with the structure, if the rails of the railway are also in contact at any part of the structure a metallic connection for the current is at once established. To remedy this the pipe is sometimes insulated from the structure by wood or other insulating material which can withstand the stress of the weight. Another method is to use insulating joints at both ends of the bridge in the pipe. Metallic connections are sometimes formed between the rails and piping system by gate boxes of metal, sometimes consisting of pipes which rest on the valve in the main pipe and terminate at the street level with a metallic cover. These are occasionally found in contact with the rail. The best remedy is the use of a wooden gate box, for its only use is to enable the valve below to be operated from the surface. Service gas pipe has also been found in contact with the rail. When permitted by the water company metallic connections were frequently made between the rail and pipe in early days, and in all probability many of these still exist. In some cases they were undoubtedly made when their advantages or disadvantages were not fully understood. These should be located and removed if it is found that the current flows from the rail to the pipe through them. Under some conditions, where the current flows the other way, it may be advantageous to allow them to remain, and thus relieve the pipe, especially if the power station is nearby and the rail return not overloaded at that point. There are various other ways in which the metallic connections between rails and piping systems may have accidentally been formed, and the important question is how to locate them exactly.

It may be accomplished by dragging metallic brushes over the rails, mounted on a separate truck, the two wheels of which are insulated from each other. The usual practice is to place a pair of these brushes on each rail, 4 feet apart, and connect

them to a milli-voltmeter. The instrument will show the direction of the current in the rails at all times, and while it will be normally toward the power station, if there is a metallic connection with a pipe the flow of current on the rail will reverse and flow away from the power station if near the connection, and will again reverse as the point is passed over by the brushes. It is then known to be between the test car and the power station. By passing over these points several times the point of connection can be located within a very few inches. It is usually necessary to carry on the car a rheostat with a capacity of 100 to 200 amperes, to be used directly between the trolley and the track in localities where the normal current density in the rails is low. A negative return feeder connection to the rails will give exactly the same indications on the instrument, but these feeder connections are known to the railway company and should not be confounded with connections to pipes. It should be understood also, in making this test, that there are other causes for the reversal of the current in the rail. Intersecting railways at grade, both steam and electric, will sometimes cause it, due to bad bonding at these points. In a city system especially, the return current does not always select the shortest paths to the power station, but will take that of least resistance, and, where a stretch of bad bonding occurs, the current will reverse and return over some other parallel line. Careful observation will soon enable the engineer to distinguish between the different causes of reversal.

Some gas companies have successfully avoided electrolysis by using insulated pipe joints, thus breaking the continuity of the system as an electrical conductor. In some cases, where the water main is laid directly under the track, a plate of cast iron was placed in the ground between the pipe and track, and electrically connected to the pipe. This had the effect of transferring the electrolysis from the pipe to the plate, and in strictly local conditions it is a good preventive of damage.

In some city railway systems, where radial or parallel lines offer different degrees of conductivity due to good and bad bonding, the current will leave the poorly bonded track, enter the intervening piping system and cross over and return through the well bonded track. When this shuttling action

occurs on the intervening pipes, the pipe paralleling the well bonded track becomes positive to the rails throughout its length. The remedy for this is, of course, the rebonding of the track which requires it.

In any system it is very important to locate all metallic connections between the pipe and rail which have been purposely made, and determine their value as an auxiliary return circuit to the power station. If the current returned to the station through a negative feeder connected to the piping system in the vicinity is not over 5 or 10 per cent. of the total return, it is safe to assume that there are no metallic connections on the system, but that the current so returned comes from earth leaks.

Reducing the rail resistance increases the flow of current on the rails and, proportionately, reduces the portion of the current returned by the pipe system. If the ground return feeders from the rails to the negative bus are connected to the rails at points symmetrically located with reference to the volume of current they return, a large unipotential area can be formed in the vicinity of the power station. This means that if one or more points on the railway not very far from the station are congested by traffic and the current density in the rails at these points is high, negative feeders connected to the rails at these points will relieve the vicinity of the power station and reduce the risk of electrolysis. This arrangement brings down the potential difference between the pipes and rails in the area surrounding the station to a point where it will not be sufficient to produce a destructive action on the pipe system. In a large city with properly connected negative feeders it is found that the neutral area floats over considerable territory dependent upon momentary conditions of the load, with the result that the pipe becomes positive to the rail one moment and negative the next. The alternating action thus set up renders electrolysis impossible where it occurs.

A common method of protecting the pipes is the so-called "drainage system," where negative feeders are connected to the pipe system and conveyed back to the power station. This method has been used quite extensively and with fair results, but it must be intelligently done or damage may still occur. In attempting to use this method the piping system should be

carefully studied, as it has been found that certain mains form an arterial system through which the majority of the current returns. These are obviously the pipes which should be bled of their current, and not a small pipe near the power station which might become overloaded with current, producing a considerable fall of potential along its length, and creating a potential difference through which electrolysis might result.

It is often important to determine the amount of current flowing through a pipe, and the best method of doing this, where the pipe can be exposed, is as follows: Connect the leads from a milli-voltmeter to the pipe, 4 feet or 6 feet apart, to measure the drop or fall of potential along the pipe. Just outside these points connect two clamps carrying a low resistance cable between them, in which are inserted an ammeter and switch. Read the milli-voltmeter when the switch is open, and again when it is closed, and also the current through the shunt cable. After a few readings it will be found that the difference in drop, with the switch open and with it closed, will bear a constant relation to the current through the shunt wire. From this the pipe can be calibrated in milli-volts per ampere and correct results obtained.

In beginning the electrolytic survey of a city it is the custom to measure the potential difference between the water system and the rails at a great number of points. For this purpose clamps are used for making connections to hydrants. An important addition to the potential measurements not always employed is the use of a shunt cable, including an ammeter and switch, connected to the hydrant and rail, independently of the pressure wires. It is then used exactly as in measuring current flow on a pipe above described. It enables the engineer to determine other conditions not shown by the potential test alone. The resistance of the earth between the pipe and rail can then be determined in each instance, and serious conditions are seen almost at a glance. If, on closing the switch, the voltmeter needle falls nearly back to zero, it indicates a very high earth resistance, and when it falls very little with a high current and the voltage is at a dangerous point trouble may exist.

Potential contour maps are of great use in obtaining a gen-

eral idea of the situation. From the readings obtained above, a map based on potential readings only can be made by drawing lines on a map of the city through points of equal potential, say red in color for readings where the pipe is positive to the rail and black where it is negative. A zero line will also be found which can be dotted or indicated in another color. This shows where the potential differences changed sign, and it usually indicates the maximum flow of current on the pipe system. In appearance such a map is not unlike the daily weather map issued by the Weather Bureau. Such a map shows at a glance the positive and negative areas in the city and indicates clearly where electrolysis may occur. The general condition of the bonding can be seen reflected by the pressure areas.

Another form of contour map is made by taking potential readings at various stations in the city between the rails at these points and the negative bus bar at the station, and also between the pipe system at the same points and the bus bar. To do this, of course, one pressure wire is needed leading back to the station, and it is necessary to request the assistance of the local telephone company in most cases, who can make the connection through their distribution board at the exchange. Electrolysis is now much better understood than formerly and troubles arising from it are not so frequent, due to intelligent remedies, and especially to better bonding of the track.

INDEX

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